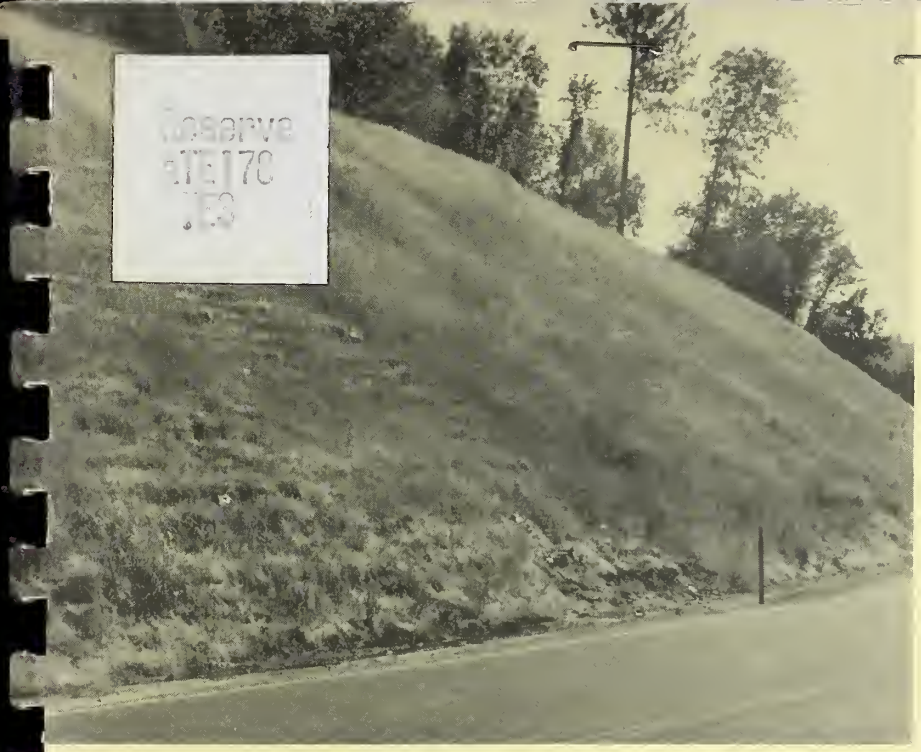

HIGHWAY RESEARCH REPORT

PLANT MATERIALS STUDY

A Search for Drought-Tolerant Plant Materials for Erosion Control, Revegetation, and Landscaping along California Highways

FINAL REPORT,
JUNE 30, 1976

Sponsoring Agency:

STATE OF CALIFORNIA
BUSINESS AND TRANSPORTATION AGENCY
DEPARTMENT OF TRANSPORTATION
OFFICE OF LANDSCAPE AND ARCHITECTURAL DESIGN
SACRAMENTO, CALIFORNIA 95804

In Cooperation with the:

U. S. DEPARTMENT OF TRANSPORTATION,
FEDERAL HIGHWAY ADMINISTRATION

By:

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
DAVIS, CALIFORNIA 95616

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Many individuals of government agencies and private businesses have helped with parts of the study--in particular, the late Dr. Eamor Nord of the U.S.F.S., Forest Fire Laboratory, Riverside, and personnel in the Forestry Division of the Los Angeles County Fire Department, the California Department of Transportation, and the U.S.D.A. Soil Conservation Service.

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16. Abstract

Plant materials were assembled, propagated, and established along California state highways. Grasses, legumes, and the California poppy were evaluated for erosion control, fire control, and aesthetic purposes. Shrubby species were evaluated for revegetation and general landscaping. Emphasis was placed upon drought-tolerant, low-growing plants which would require a minimum of maintenance. A herbaceous seeding guide and a list of native shrubs and trees were prepared for California, classified by major land resource areas. Special and supplementary studies relevant to plant propagation and establishment were conducted. Whenever possible, the plants were evaluated on representative highway sites using common methods applied by contractors. Most data were collected by visual observation, no statistical analyses were made beyond simple arithmetic averages. Some continued monitoring of plantings is recommended to assess anticipated future changes.

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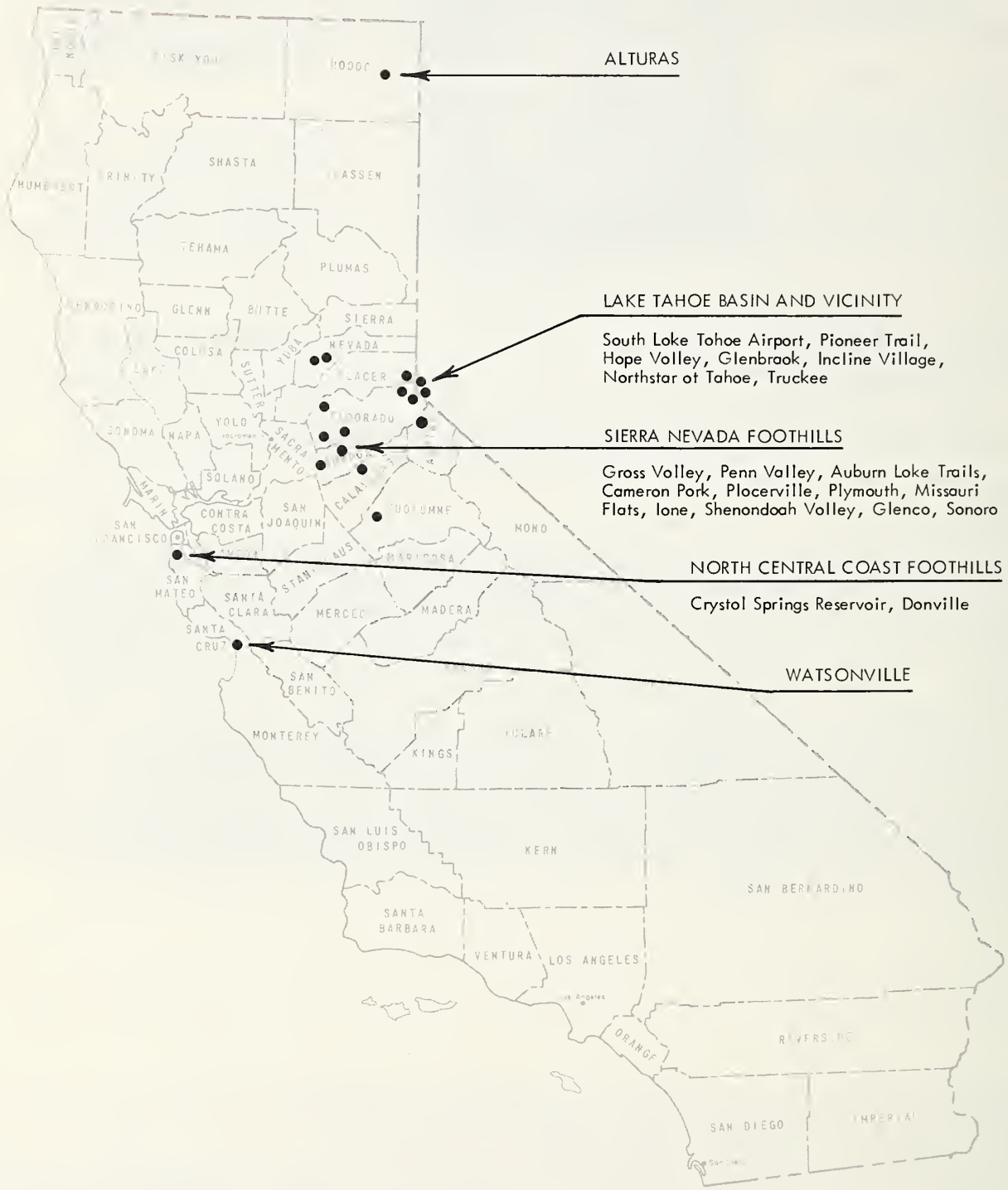
GENERAL LOCATION MAP OF HERBACEOUS AND SHRUB TEST AREAS IN THE PLANT MATERIALS STUDY



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I. INTRODUCTION

For many years, barley and annual ryegrass had been used for erosion control on highway cut and fill slopes by the California Department of Transportation (CALTRANS) (2). Both species gave outstanding results for early erosion control but left a heavy mat of unsightly vegetation that sometimes persisted for several years. Barley rarely reproduced beyond the first year, and ryegrass often disappeared in a few and eventually native annuals took over.

In recent years new grasses and legumes had been developed for seeding rangeland and watersheds. CALTRANS wanted to evaluate these grasses for volume of fuel, appearance, cost, and erosion control.

CALTRANS was also searching for drought-tolerant shrubs to use as screens on disturbed sites in semi-urban areas and for low-spreading shrubs to use as bank covers. Shrubs for revegetation were needed in rural areas.

In order to fill these plant needs, the CALTRANS Office of Landscape and Architectural Design (OLAD) in Sacramento signed an agreement with the USDA Soil Conservation Service (SCS) in Davis, in cooperation with the Federal Highway Administration to search for better plants.

The study had four main objectives: 1) to evaluate and select or develop self-perpetuating, drought-tolerant annual and perennial grasses and legumes, and other ground cover plants for erosion control; 2) to evaluate and select native shrubs and trees suitable for revegetation; and to develop propagation and cultural procedures for increasing the bareroot stock of native species such as manzanita; 3) to evaluate shrubs for general landscape use; and 4) to conduct special studies.

There were four special studies: 1) to develop seeding rates for cereal grains and grasses used in emergency erosion control on a "best-result" basis; 2) to evaluate the response of native plants, particularly the California poppy, to herbicidal sprays used by CALTRANS; 3) to determine the practical effects of foliar antitranspirants in establishing shrubs; and 4) to develop methods of perpetuating the California poppy within highway rights-of-way.

The scope of the study was statewide except that the establishment of native shrubs in the Tahoe Basin was to be studied by the University of California, Davis (U.C. Davis). Areas of priority were assigned to: 1) the north-central coastal foothills, 2) the Sierra Nevada foothills, 3) the Tahoe Basin and vicinity, and 4) Alturas. As a result, better grasses were found for long-term erosion control, fire control, and aesthetics. Drought-tolerant shrubs were found for revegetation, as well as ways of establishing them. Some problems still exist in establishing grasses on steep coarse-textured parent material soil in mountainous areas.

The procedure used in the study was to test plants that had promise by using common methods of establishment. Both native and exotic plants with suitable characteristics were sought. Species which would attract wildlife to the highways were avoided. To obtain the plant material, either as seed or plants, purchases were made through com-

mercial sources. Those plant materials not purchased were grown at the SCS Lockeford Plant Materials Center. The plants were tested under different cultural methods on an assortment of cuts and fills with different soils, slopes, exposures, and climatic conditions. Evaluations in the study were made by visual appraisal of success, without statistical analysis.

Using the results of the study, CALTRANS will have better plant species for use in highway plantings, whatever the purpose and conditions.

Methods of establishment have been reviewed for success and modified as necessary or new ones developed. Promising species have not reached maturity; their progress should be monitored for several years.

Trade names of various products used in the report are solely to provide specific information. Mention of a trade name does not constitute a guarantee of the product by the U.S. Department of Agriculture nor does it imply an endorsement by the Department over comparable products that are not named.

II. GENERAL CONCLUSIONS, RECOMMENDATIONS, AND IMPLEMENTATIONS

The conclusions, recommendations, and implementations developed are included separately after each study, as shown in the Table of Contents. They are not presented in total in this section because many studies were involved, making separate presentations at the end of each study more appropriate.

CONCLUSIONS

Grasses and Legumes for Erosion Control

The better annuals in the central coastal and Sierra Nevada foothills for which seed is commercially available are 'Wimmera 62' ryegrass, annual ryegrass, 'Blando' brome, rose clover, and 'Lana' vetch. COMMON AND SCIENTIFIC NAMES ARE LISTED IN APPENDIX D. The mixture that most rapidly develops is 'Wimmera 62' ryegrass and 'Lana' vetch, but 'Lana' vetch is difficult to mow and 'Wimmera 62' ryegrass leaves a mass of unsightly residue for a year or two. 'Blando' brome and rose clover is a persistent better appearing mixture and has a lower fuel volume. Four promising annual grasses in trial status are foxtail fescue, red brome, big quakinggrass, and annual bluegrass. Red brome grows well with the California poppy but is of questionable persistence. The better perennial grasses are 'Luna' pubescent wheatgrass and 'Palestine' orchardgrass. Perennials do not develop as rapidly as annuals but, where well established, they provide tight, low-growing, late-maturing, long-lived erosion control covers. At lower elevations hydromulch seeding is adequate but erosive areas need better protection as received from straw mulch.

In the Tahoe Region and vicinity, 'Luna' pubescent wheatgrass and 'Tegmar' intermediate wheatgrass have been the better grasses; of secondary importance are orchardgrass, 'Fairway' crested wheatgrass, 'Durar' hard fescue, and 'Sherman' big bluegrass. Cicer milkvetch has been the better legume. Hydromulch seedings at higher elevations are dependent upon favorable surface soil moisture relationships. If the soil surface stays moist long enough in the spring for germination and establishment the seeding is successful. If not, failure is likely to occur. At higher elevations, stands are most successful if the seed is placed into the moist soil beneath the dry surface layer. One way of insuring success while providing protection is to incorporate the seed into the soil while tucking the straw in. A modified sheepsfoot roller makes depressions in the soil for the seed to fall into and become covered. Variations of this method sometimes fail in decomposed granite because its moisture-holding capacity is low and the seedlings die after emergence. Spring seedings generally have given better results than fall seedings. At Alturas, the best perennial grass species was 'Fairway' crested wheatgrass, followed closely by 'Luna' pubescent wheatgrass, 'Tegmar' intermediate wheatgrass, and 'Sherman' big bluegrass. No legume was successful. In the Tahoe Basin and at Alturas the best cereal grain was cereal rye.

Fertilization with nitrogen is necessary for good initial growth, the rate varying with average precipitation and erosion hazard to a maximum of 80 pounds actual nitrogen per acre. Phosphorus and sulfur are usually included in the formulation although they may not be necessary.

Once a grass-legume cover is established and initial erosion control provided, there seems to have been little need for maintenance. Covers of annual grasses have been improved by applying nitrogen fertilizer, but that is at the expense of legumes and other broadleaf species and sometimes perennial grasses. Deteriorating old slopes with suitable herbaceous covers have been improved by hydrofertilizing, or by hydromulch seeding with adapted herbaceous species and fertilizing.

Shrubs for Revegetation and General Landscaping

The best shrubs tested for revegetation and general landscaping in the foothills, in descending order of success, were coyote brush, fourwing saltbush, rockrose, California buckwheat, whiteleaf manzanita, buckbrush, quailbush, oleander, and wartleaf ceanothus. These were established successfully where the soils were not too droughty, where competition from herbaceous species was nearly nil, and where mice, grasshoppers, and other predators were controlled. Rockrose and oleander grew well but are not considered desirable for revegetation by OLAD since both are Mediterranean exotic species. Rockrose and California buckwheat are low-growing and somewhat spreading and could be broadcast seeded for drought-tolerant bank covers. Quailbush is the only native tested which is evergreen and grows rapidly enough to be a screen, but it sometimes tends to become scraggly. Promising shrubs in trials for ground covers have been creeping sage and 'Bandera' Rocky Mountain penstemon, but is too early to evaluate these results.

In the Tahoe Basin and vicinity the best non-native species were 'Bandera' Rocky Mountain penstemon, Caucasian sage, bearmat manzanita, and two varieties of arctic willow. The best native plants were sulfur flower buckwheat, big sagebrush, greenleaf manzanita, mountain pride penstemon, rubber rabbitbrush, squaw carpet ceanothus, and redosier dogwood. These shrubs generally established better on finer grained volcanic soils than on coarse-textured granitic ones.

Shrubs were established from container-grown stock usually 7 to 14 months old. They were fertilized with slow-release fertilizer at 0.29 ounce of actual nitrogen per plant. In a fertilizer formula 10-0-0, N-P-K, 10% of the fertilizer is actual nitrogen; so to apply 0.29 ounce of actual N, 2.9 ounces of fertilizer needs to be applied. Phosphorus and potassium were also included in the fertilizer. The size of some shrubs was increased and this was attributed mainly to nitrogen. Survival was not increased. Irrigation at planting seems necessary only if the soil is not moist. Irrigation during the summer caused little or no response, though it is felt there should have been some; perhaps the amount of water was not adequate or the intervals between irrigations were too great. Results were generally poor

from direct seeding. At lower elevations some species germinated readily but were killed by competition or drought. As with container-grown plants, herbaceous competition must be low for the young plants to survive. Results were poor to good from bringing dormant seeds in with topsoil from shrubby areas although herbaceous competition must be minimal. Shrub plantings are not recommended at Alturas because there is little need and because big sagebrush and rubber rabbitbrush could volunteer from windblown seed.

Propagation of Shrubs

All shrubs were propagated either from seed or cuttings. Some were easily propagated, while others were difficult. Even though prescribed procedures were followed, further innovations were sometimes necessary to acquire acceptable production.

Propagation and Establishment of Bareroot Stock

Bareroot stock of several native shrubs were propagated in beds from either cuttings or seed. At lower elevations, establishment was nearly as good as with container-grown stock, though growth was less in the first year.

Special Studies

1. SEEDING RATE TRIALS FOR EMERGENCY EROSION CONTROL.

Forty pounds of seed per acre seems satisfactory for seeding of grasses and legumes where erosion is not critical. A higher rate assures more seedlings early in the season. Until the many variables that affect soil erosion and plant cover development can be determined, evaluated, and controlled there is little need to attempt to determine seeding rates except on a gross basis. Where there is a critical situation, the more rapidly developing species such as barley, annual ryegrass or 'Wimmera 62' ryegrass should be used.

2. RESPONSE OF NATIVE PLANTS TO HERBICIDE SPRAYS ON HIGHWAY FIRESTRIPS.

No winter active herbaceous species seemed immune to herbicide sprays applied by CALTRANS. Many shrubs and tree seedlings, however, remained alive in the spray strip. The sprays did not appear to drift in the air or be moved downslope by water.

3. USE OF FOLIAR ANTITRANSPIRANT SPRAYS IN ESTABLISHING DROUGHT-TOLERANT SHRUBS ALONG ROADSIDES.

This study was inconclusive since the shrubs that were tested and appeared most likely to benefit from antitranspirant sprays were those that were found most easy to establish.

4. PROMOTING GROWTH AND PERPETUATION OF CALIFORNIA POPPY WITHIN THE HIGHWAY RIGHT-OF-WAY.

Poppies seem to persist only in rocky, gravelly, or sandy soils where herbaceous species offer little competition. Fertilization increased grasses at the expense of poppies. Mowing may be one way of perpetuating poppies. Mowing in April allowed the poppies to recover and continue growing while greatly reducing grass competition. Poppies have persisted better with foxtail fescue than with red brome or 'Blando' brome at the Lockeford PMC.

Supplemental Studies

1. A COMPARISON OF CEREAL GRAINS FOR EROSION CONTROL.

At lower elevations, barley generally developed more rapidly than wheat or oats. It was superior to cereal rye in that rye was much taller. The best barley varieties were 'Briggs,' 'CM 67', 'Numar,' and 'Blue Mariot' barleys. At Ione, 'Casbon' barley was better than 'Briggs.'

2. FIBERGLASS ROVING-ASPHALT EMULSION FOR EROSION CONTROL.

The fiberglass roving-asphalt emulsion easily conformed to soil irregularities and provided excellent erosion control. Grasses and legumes emerged through the fiberglass netting and asphalt when application was at prescribed rates but failed to do so in small areas of overapplication.

3. FERTILIZER TRIALS.

Nitrogen fertilizer is necessary on highway slopes, which are mostly of parent material low in nitrogen. In simple trials, ammonium phosphate sulfate fertilizer 16-20-0 had declining effectiveness on plant growth beyond a rate of 500 pounds per acre. Such a high rate appears questionable in some areas, particularly on slopes of lower erosion hazard.

4. DRIP IRRIGATION.

Drip irrigation proved an easy way to irrigate shrubs. However, there was little or no response by buckbrush and whiteleaf manzanita on the deep soils at the Pleasanton Plant Materials Center.

5. EFFECT OF AMMONIUM PHOSPHATE SULFATE 16-20-0 FERTILIZER ON SEED INOCULANT.

Ammonium phosphate sulfate at the rate of 500 pounds of 16-20-0 in 3000 gallons of water had little or no adverse effect on 'Lana' vetch inoculant within 4 hours in laboratory trials at Pleasanton. The

pH of the solution was 6.5. However, the results might have been different if the solution had shifted more to acid. No effect was noticed on germination of 'Blando' brome seed within 24 hours, although 'Lana' vetch germination decreased 25% within 4 hours.

RECOMMENDATIONS

The findings, both completed and partially completed, represent a substantial gain in practical information applicable to current needs in erosion control, revegetation, and general landscaping along California highways. It is recommended that this information be incorporated into specifications or otherwise used where possible, and that the results of using it be monitored for any needed adjustments.

IMPLEMENTATION

All information is directly applicable to growing or managing drought-tolerant vegetation along California highways. Information from parts of the study is already in use.

III. GRASSES AND LEGUMES FOR EROSION CONTROL

For erosion control on both cut and fill slopes, the grasses selected are expected to germinate and establish rapidly, protecting the soil from beating raindrops and anchoring soil particles in place. Meeting these criteria in the Mediterranean-type climate are cereal grains and aggressive annual grasses such as annual and 'Wimmera 62' ryegrasses, 'Blando' brome, and foxtail fescue. Annual grasses start growth in the fall and by spring make dense effective ground covers. Legumes are added to increase nitrogen and to provide colorful flowers as well as cover. At higher elevations the situation is drastically different. There are no aggressive annual grasses except cheatgrass and cereal rye, both usually considered undesirable weeds. Germination usually takes place in the spring since the fall is cold and droughty and the winter covers the soil with snow. By summer, the slow-developing perennial grasses and legumes seeded at higher elevations are little more than slender seedlings, scarcely providing any soil protection in the first year.

Besides searching for more effective grasses and legumes for erosion control, this Study has also been concerned with other important characteristics of plants such as persistence, volume of fuel (fuel volume), how long the plants stay green in the summer, and aesthetic qualities.

The herbaceous part of the study concentrated first on developing grasses and legumes already used for range improvement, watershed protection, and fire hazard reduction. Considered next were native or naturalized annual grasses and legumes (these naturalized species were brought in by the Spaniards and largely replaced the native species), particularly those growing on droughty, shallow, or infertile soils. Exotic species that have special uses in highway plantings were requested.

From 1970 to 1975, 53 species or varieties of grasses and legumes and the California poppy were tested, singly or in mixtures, in the coastal and Sierra Nevada foothills. Fifty-four herbaceous species were tested in the Tahoe Basin and Alturas. Methods used by contractors, or variations necessary to conduct the trials, were used in establishing them, with special techniques tested for difficult situations. A small part of the evaluations dealt with fertilizing existing stands and fertilizing and seeding old bare slopes.

METHODS OF ESTABLISHMENT AND MAINTENANCE

METHODS OF ESTABLISHMENT

For erosion control a stand of plants is a failure if it does not provide effective cover. Worse than the waste of valuable seed is that the purpose has not been achieved. Even when the species seeded are well adapted, the seedbed must be rough and the seeding done by prescribed procedures. Otherwise, failure is probable, with the resulting cover being of poor quality, only partially effective, and possibly a fire hazard. Just as in construction work, planning for erosion control must be based on all known facts. Except for the vicissitudes of weather, success can then be predicted with fair accuracy. One of the most important things to keep in mind is that the seed must be in contact with moisture long enough to germinate and root. Also, since plants require food to grow, fertilization is needed because the cuts are usually made through infertile parent material. Lastly, when perennial grasses are to be established on old slopes that have annual grasses and other weeds, the competition should be removed before seeding. Care should be taken not to leave the slope erodible.

Two practical methods of seeding used by CALTRANS have given consistently good results. At lower elevations and where the erosion hazard is not high, a common effective method has been to hydroseed by spraying seed, wood-fiber mulch, and fertilizer on the slope in a water slurry. Where the erosion hazard is high, straw has been used to protect the soil from erosion until a vegetative cover develops. Both methods were used in this study. Few areas in California have been seeded by drilling, a positive way to establish grasses and legumes on more gentle slopes.

Species

The grasses and legumes and other herbaceous species that were selected for testing on low elevations are listed singly and in mixture in Appendix Table 14, page A-3. For high elevations the listings are in Appendix Table 17, page A-22. These consist of annual and perennial grasses and legumes and the California poppy. Tests of most species were replicated by seeding at several sites each year from 1970 through 1973 in the areas for priority testing shown on page 1.

Shrubs were sometimes seeded with the herbaceous species, as discussed in the "Shrubs for Revegetation" section of the Report.

Seeding and Mulching

An early policy in the study was to test the plants under field conditions using seed methods used by contractors such as hydromulch seeding and straw mulching. These procedures had to be modified, however, for use in the smaller scale but more complex operation of the study. In hydromulch seedings the seed was broadcast by hand before

the slurry of wood fiber and fertilizer was applied. This deviation was made because the seed was very difficult to clean out of the hydromulcher tank and at each study site the tank would have had to be cleaned out about 60 times. The straw was punched in with a spade instead of a commercial straw puncher because a commercial puncher was too difficult to use on small plots. Commercial operations were used on some large plots, however, and seed was mixed in with the wood-fiber fertilizer slurry and sprayed on the slopes, or the straw was punched in with a commercial rig.

The seeding rate for seeding single species and mixtures was 40 pounds per acre except for the large-seeded cereal grains, where 90 pounds per acre were used. Trials were conducted to determine optimum seeding rates as discussed in Special Study 1.

Wood-fiber mulch was applied at 1,500 to 3,000 pounds per acre. Originally, application at both higher and lower elevations was 1,500 pounds, but that was later increased to 3,000 pounds at higher elevations to improve germination and establishment. At most test sites at least one plot was mulched with wheat or barley straw to compare straw mulch with wood-fiber mulch. Hand-spread straw was applied at two tons per acre and punched in with a garden spade. When the straw was applied commercially, 4 tons were applied in two applications.

Other mulches included dry cow manure at 10 tons per acre, and bark chips at 10, 15, and 30 tons per acre.

Near the end of the study, a fiberglass roving-asphalt emulsion mulch was applied over graded waterways that had been seeded and fertilized. The fiberglass was spread over the soil surface at about 0.5 pound per square yard, and the asphalt emulsion sprayed over the fiberglass at 0.10 to 0.28 gallon per square yard. This study was conducted by CALTRANS. The results are reported in Supplemental Study 2.

Ammonium phosphate sulfate fertilizer 16-20-0 was applied at 500 pounds per acre (250 pounds in the Tahoe Basin). When other ammonium phosphate formulas were used, the amount of nitrogen applied was the same as with 16-20-0.

Time of Seeding. Seeding time at lower elevations varied from September to November, with September most successful. Seedings were made in the Tahoe Basin and Alturas in October or November, or in April or May, as soon as possible after snowmelt.

Plot Size. The size of the plots varied with the length of the slope but was usually 10 x 30 feet. Promising mixtures were tested in larger plots (up to 2 acres).

Site Selection. In areas of new construction, sites with representative soils were selected whenever possible, particularly where there were extensive uniform slopes. Some sites were not representative, but they were the only ones available. Site selection was one of the most difficult problems encountered. Areas in old construction were avoided, if possible, particularly where the slopes were eroded or the soil material compacted or where indigenous weeds were present to compete with the seeded species. Nonuniform slopes were avoided. Slopes steeper than 1.5:1 were also avoided because the seed and mulch were likely to slide down. Whenever possible, areas were selected

with both northerly and southerly exposures on cut and fill slopes. Not all sites were on California highways. With the approval of CAL-TRANS, and in agreements with other agencies or owners, sites were selected along Nevada highways; along county roads in Nevada, Placer, El Dorado, and Amador Counties; along a road constructed by the Bureau of Land Management; and along roads in two private development projects, Northstar at Tahoe and Auburn Lake Trails.

Toxic and Droughty Soils. When soil conditions were adverse for establishment and plant growth, as on toxic or droughty soil materials, topsoil was spread over the soil surface to provide a medium for plant growth. This included the application of 2 inches of topsoil (or at least fairly good soil) over the problem soils. Whenever possible, the topsoil was bonded to the slope by running a tractor over it. On droughty soils, the seed was placed in small contour furrows made with a hoe to get the seed below the dry surface and into moisture and then covered with soil.

METHODS OF MAINTENANCE

Maintenance trials on highway cut and fill slopes were limited to fertilizing after the first year with ammonium phosphate sulfate 16-20-0 at 200 pounds per acre and at the Lockeford PMC to fertilizing and mowing stands of grass-legume-poppy seedlings. The methods and results are described under Special Study 4, "Methods of promoting growth and perpetuation of the California poppy within the highway right-of-way."

To maintain a protective cover on a steep eroding cut slope south of Placerville and a fill slope at Incline Village, they were hydromulch seeded and fertilized as a part of maintenance operations. In both instances, the public disliked the poor appearance of the slopes.

RESULTS

The results of trials with herbaceous species, mainly grasses and legumes, are described in three sections: 1) lower elevations in central coastal and Sierra Nevada foothills, 2) higher elevations in the Tahoe Basin and vicinity, and 3) Alturas, in the modified continental-type climate of northeastern California.

1. NORTH-CENTRAL COASTAL AND SIERRA NEVADA FOOTHILLS

The north-central coastal and Sierra Nevada foothills are combined here since the results are similar. This is not surprising since both are in the Mediterranean-type climate, both are at lower elevations, usually below 2,000 feet elevation with similar average annual rainfalls, and both have many of the same native species, particularly grasses.

These areas have had a great deal of new highway construction, not only around the San Francisco Bay Area but throughout the foothills. There has also been a continual widening and relocation of old highways to bring them to modern standards. Some of the highways are in critical watersheds, such as the new freeway skirting the edge of Crystal Springs Reservoir, a water-holding reservoir for partial municipal water supply to San Francisco.

Most of the test sites were south of San Francisco or in the Sierra Nevada foothills in the vicinity of State Highway 49 from Mariposa to Grass Valley. At Watsonville, a test area was located at the edge of the coastal redwoods; at Grass Valley Airport one was located at the lower edge of the ponderosa pine forest of the Sierra Nevada mountains. Information about the locations, exposures, soil series, and soil parent materials is found in Appendix Table 13, page A-1. Since the test sites at most locations were excavated well into parent material, the soils were mostly either fractured rock or mechanically fragmented rock material. The sandy soil material at Watsonville was highly erosive.

Trials were made in each fall from 1970 to 1974.

SPECIES ADAPTATION

Single species. Fifty-three grasses, legumes, cereal grains, and the California poppy are in various stages of evaluation on highway slopes in foothill areas and at the Lockeford Plant Materials Center. Appendix Table 14, page A-3, evaluates these and other herbaceous species seeded singly and in mixtures. In addition, nine wheat and barley varieties were studied in Supplemental Study 1, "A Comparison of Cereal Grains for Erosion Control," page 128. Common names have been used and the botanical equivalents are listed on pages D-1 through D-9.

Photo 1. A typical evaluation site for grasses, legumes, and the California poppy at Crystal Springs near San Francisco.

Annual grasses. The best annual grasses for erosion control with seeds grown commercially have been 'Wimmera 62' ryegrass, annual ryegrass, and 'Blando' brome. 'Wimmera 62' developed rapidly, faster than 'Blando' brome. 'Wimmera 62' also formed a dense vegetative cover, which was especially advantageous where the erosion hazard was high, and this old growth provided excellent soil protection up to two years. Unfortunately, this stemmy old mat has often been unsightly and little else grows there for several years. Annual ryegrass has been similar to 'Wimmera 62' ryegrass, though less able to mature, develop seed, and perpetuate itself under droughty inland conditions. The inability of annual ryegrass to reseed is advantageous when desirable native species are able to rapidly occupy the area and provide erosion control. Although 'Blando' brome grew more slowly than 'Wimmera 62'

Photo 2. 'Wimmera 62' ryegrass (left) is coarse textured while 'Blando' brome (right) has a soft appearance, blending well into the landscape.

ryegrass, it grew early and gave a cover that provided good soil protection. 'Blando' brome blended well with surrounding grassy landscapes where soft chess (the common name for 'Blando' brome) is usually a large component. 'Blando' brome also perpetuates well. For these reasons, 'Blando' brome would be a better choice than the ryegrasses unless the slope was subject to severe erosion, hence requiring the most dense cover possible.

Other annual grasses were seeded in trials, although seed was not commercially available. These were several naturalized Mediterranean grasses, including foxtail fescue, red brome, annual bluegrass, and big quakinggrass. Foxtail fescue persisted well on shallow cut slopes but not on deeper fill slopes where naturalized taller grasses such as wild oats or ripgut brome could overtop it. At Ione foxtail fescue grew well on sedimentary rock soil with a very acid condition (pH 4.5). It also developed a rapid soil cover during a cold winter on Aiken soil materials at the Grass Valley Airport where the other grasses grew poorly. Foxtail fescue should be considered for future use because it provided rapid and enduring soil protection under several

Photo 3. Foxtail fescue is in initial seed increase at Lockeford Plant Materials Center. This seed will be used for further evaluations on highway slopes and later as a source for commercial seed production.

difficult conditions. Red brome, which is commonly found in areas of low rainfall or on dry hills has persisted on a dry south-facing cut slope at Crystal Springs, but not on fill slopes. It grew well with California poppy and rose and crimson clovers. Since it has a colorful reddish hue during maturity and is also short, the poppy and legume flowers are exposed, making a colorful combination. Unfortunately, seed production for red brome has been poor at the Lockeford PMC probably because the alluvial soils are more moist in winter than those in drier areas.

Photo 4. Red brome (right) grows well with California poppy since it is not highly competitive, is short, and has a reddish hue which blends well with the poppy flowers.

Two other grasses studied in more recent trials were annual bluegrass and big quakinggrass. Annual bluegrass has excellent potential

Photo 5. Annual bluegrass growing in the median strip is an early growing, rapidly developing grass that could be useful for erosion control as well as in fire control.

for an early developing erosion control cover of low fuel volume, particularly in areas where it can be maintained free of taller growing grasses. Big quakinggrass has decorative seed heads, is short, does not appear very competitive, and might be used advantageously with poppy and wildflowers for aesthetic purposes. Tests with 'Cucamonga' brome, the most rapidly developing tall-growing grass, were discontinued because the seedlings froze at Placerville, the mature stems are somewhat harsh appearing, and it disappears within two years in the northern climate.

Perennial grasses. Four perennial grasses show promise for use on fills as well as on some cut slopes at lower elevations. These were 'Luna' pubescent wheatgrass, 'Palestine' orchardgrass, 'Hardinggrass,' and 'Perla' koleagrass. At Cameron Park none of the perennials persisted well on a hot south-facing slope cut through dense parent material.

Photo 6. 'Luna' pubescent wheatgrass (left) forms a tight, low cover while Hardinggrass (right) is much taller.

'Luna' pubescent wheatgrass, being a rhizomatous species, was very promising for long-range erosion control but slow growing. 'Luna' pubescent wheatgrass is short at lower elevations and stays green longer than annual grasses, two factors in its favor for fire control. 'Palestine' orchardgrass, a bunchgrass, grew more rapidly than 'Luna' when young but did not persist quite as well.

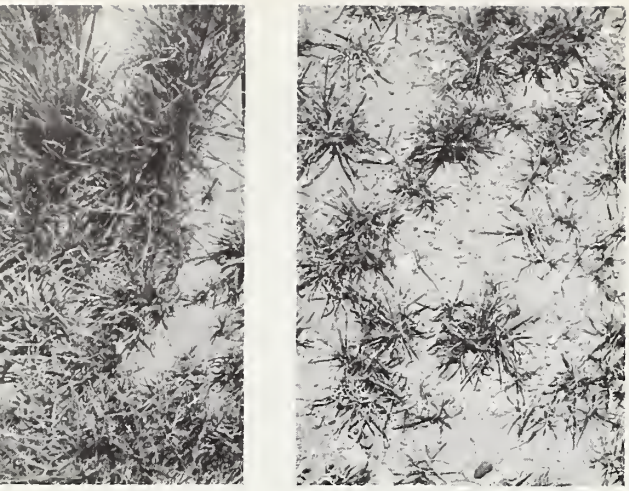

Photo 7. 'Palestine' orchardgrass (left) grew more rapidly than 'Luna' pubescent wheatgrass (right).

Photo 8. 'Palestine' orchardgrass is a vigorously growing perennial bunchgrass useful for short- and long-range erosion control and for fire control.

Two Phalaris species, 'Hardinggrass' and 'Perla' koleagrass, established well but have shortcomings. 'Perla' koleagrass, in particular, was tall-growing; both tended to become bunchy. 'Perla' koleagrass should not be seeded where a driver's vision would be obscured. The Phalaris species were also damaged by mice. The bulblike base of 'Perla' koleagrass was destroyed by mice on a fill slope at Crystal Springs. Seeded singly both species have formed some dense stands which prevented invasion of weeds. 'Perla' koleagrass, however, was by far the fastest developing perennial, and at one site at Cameron Park it surpassed the early growth of 'Wimmera 62' ryegrass. As well as forming tight covers for erosion control, the best stands of perennial grasses were so effective they kept out annual grasses and weeds such as star thistle. This was true only of the dense stands, however, and should not be construed to be a rule.

Some of the perennial grasses which grew poorly were 'Sodar' streambank wheatgrass, western wheatgrass, and seaside brome. Perennial ryegrass grew almost as rapidly as annual ryegrass in the first year, but died by the second. On a rocky cut at Crystal Springs, smilo, a drought-tolerant summer-growing grass, started slowly but made a fairly good cover by the end of the first year. Two Pennisetum species, feathertop and fountain grass, froze in the seedling stage at Crystal Springs.

Annual legumes. 'Lana' vetch developed the most rapidly of the annual legumes, forming dense stands later in the growing season, particularly in mixtures where the branches intertwined with the grass stems. 'Lana' vetch is a strong nitrogen producer. Evidenced by the greater growth of 'Blando' brome in the year following 'Lana' vetch, it was estimated that root-nodule bacteria produced the equivalent of the

Photo 9. 'Lana' vetch develops rapidly, forms dense stands later in the growing season, but "balls up" in mowing machines.

nitrogen in 250 pounds per acre of ammonium phosphate sulfate fertilizer 16-20-0. It has been somewhat erratic in persistence, however, and stays better on deep than on shallow soils. CALTRANS found dense stands of 'Lana' vetch difficult to mow, "balling up" in the mower. Rose clover has persisted very well on shallow cut slopes, often providing dense stands. Crimson clover adds colorful red flowers in the first year but in drier areas away from the coast almost disappears by the second year. Subclover, because of its low growth, may have to be grown singly, or maintained by mowing so that taller vegetation will not overtop and eventually suppress it.

Photo 10. Rose clover has persisted well on shallow cut slopes.

Perennial legumes. One perennial legume, birdsfoot trefoil, provided greenery and color at Crystal Springs but usually did not grow dense enough to be considered a primary erosion control plant. Trefoil grew best along the roadsides (where there was more moisture) and in seepage areas. Seeded singly, it has good potential as ground cover for use on more level areas, where possibly it could be maintained with minimal irrigation and occasional mowing. With moisture, it grows and flowers late into the fall. 'Rambler' alfalfa did not establish well at Crystal Springs and probably should not have been considered for use there because it is highly palatable to deer and other wildlife.

Photo 11. Trefoil flowering where runoff water from the pavement and freeway slope accumulates.

Mixtures of grasses and legumes. Fifty-three combinations of grasses, legumes, California poppy, and lupines were included in trials in the coastal and Sierra Nevada foothills. These are listed in Appendix Table 15, page A-10. Each species used in mixtures is briefly evaluated in Appendix Table 14, page A-3. There are several reasons for seeding mixtures instead of single species: 1) to provide different species to fit different environmental conditions such as soils or exposures, 2) to complement a grass with a legume, 3) to provide plants for both long-term and short-term erosion control, 4) to break up the uniform appearance of a single species (though this may be preferred by some individuals), 5) to improve appearance by seeding colorful flowering species such as crimson clover, California poppy, lupines with the grasses, and 6) to seed a colorful mixture of flowers mainly for aesthetic purposes.

After tests of many combinations of herbaceous species, shown in Appendix Table 15, page A-10, a few simple ones, based upon the superior grasses, legumes, and poppy, seem adequate for the foothill area. These are discussed under annual grass-'Lana' vetch combinations; annual grass-annual clover and California poppy mixtures; perennial grass mixtures; perennial grass-annual grass-legume and California poppy mixtures, and cereal grain-annual grass-legume mixtures. No wildflower mixtures were seeded.

Annual grass-annual clover and California poppy mixtures. A number of mixtures were seeded which included either 'Blando' brome, red brome, or foxtail fescue in combination with rose and crimson clovers, California poppy, and sometimes an annual lupine. At Penn Valley, big quakinggrass was also seeded with the clovers and poppy in the fall of

1974. These mixtures were not expected to be as dense as those with 'Lana' vetch.

'Blando' brome and foxtail fescue were the stronger grasses in the Sierra Nevada foothills, usually persisting better than red brome. At Crystal Springs, however, red brome persisted for three years on a rocky cut and also invaded plots of 'Blando' brome. Red brome is very compatible with the annual clovers and California poppy since it is not highly competitive and, being short, allows these species to overtop it and show their flowers. With fertilization, 'Blando' grows too tall for the flowers to show. The reddish hue of red brome during maturity also complements the colorful clovers and poppy. Seldom are lupines abundant enough to add color in the mixture, although in the second year at Glenco, numerous native annual blue lupines invaded the plots, creating a striking profusion of colorful flowers.

Photo 12. Lupine was seldom abundant enough to add color in grass and California poppy mixtures, but, at Glenco, native lupines invaded the plots, creating a striking profusion of colorful flowers.

'Blando' brome and rose clover were good species on cut slopes with 'Blando' providing early soil protection and rose clover persisting well in subsequent years. Foxtail fescue persisted slightly better than 'Blando' brome on a cut slope at Sonora; and in the second year, rose clover dominated the cover of both grasses.

Photo 13. Young 'Blando' brome, California poppy and rose clover plants on a fill slope at Auburn Lake Trails. By the end of the growing season 'Blando' brome was taller than the poppies.

Annual grass-'Lana' vetch combinations. These were the most rapidly developing combinations of grasses and legumes because both annual grasses and 'Lana' vetch grow rapidly when young. The most rapid developing combination was 'Wimmera 62' ryegrass and 'Lana' vetch. By spring, stands of 'Wimmera 62' ryegrass, or 'Blando' brome, or 'Cucamonga' brome in combination with 'Lana' vetch differed little in appearance since by then 'Lana' vetch dominated and overtopped the grasses. There was no visual indication that one combination retarded erosion significantly more than any other during early growth. This was largely attributed to the similarity in growth rates (even if somewhat different) and to the protection afforded the soil by wood fiber or straw mulches during these early stages. Other factors, however, will favor the 'Blando' brome-'Lana' vetch over the 'Wimmera 62' ryegrass-'Lana' vetch combination. 'Wimmera 62' ryegrass grows rapidly and makes a tremendous mat for soil protection in the first year with the residue

furnishing protection into the second. The ryegrass-vetch mat usually becomes unsightly, however, and the poor appearance may persist for a year or more. Also, 'Blando' brome generally persists better than 'Wimmera 62' ryegrass. 'Cucamonga' brome can be eliminated for the reasons discussed under single species. Annual ryegrass, foxtail fescue, red brome, and big quakinggrass were not tested with 'Lana' vetch.

Photo 14. 'Lana' vetch grows rapidly early in the year and in combination with 'Blando' brome makes a good cover.

In combination with annual grasses, 'Lana' vetch has drawbacks although it is an early and rapid grower, a soil-nitrogen producer, and one of the most compatible legumes seeded with annual grasses. In a year following dense growth, 'Lana' vetch sometimes reproduces poorly, allowing tall-growing, tap-rooted, and unsightly weeds to invade the area. The reason is not known. Also, mowing is a problem, and the volume of fuel is higher than that of most herbaceous material. 'Lana' vetch was not seeded with other annual legumes because they were shorter and it seemed reasonable that they would not be able to compete unless the seeding rate for 'Lana' vetch was perhaps as low as 5 pounds per acre.

Perennial grass mixtures. Only two perennial grass mixtures were tested since annual grasses and legumes were usually mixed with perennials, either to increase early soil coverage or to add nitrogen or color. In one mixture of 'Luna' pubescent wheatgrass, 'Tegmar' intermediate wheatgrass, and 'Sodar' streambank wheatgrass, only 'Luna' pubescent wheatgrass was successful, dominating the mixture.

Since the mixture was predominantly 'Luna' pubescent wheatgrass, the cover developed slowly and provided little soil protection in the first year. In the second year, this cover was dense and low-growing, good for erosion and fire control and pleasing in appearance.

When 'Perla' koleagrass, 'Luna' pubescent wheatgrass, and 'Palestine' orchardgrass were seeded together on a cut slope through sandstone rock at Crystal Springs, 'Palestine' orchardgrass dominated the mixture, apparently being very competitive where the soil was shallow and rocky.

Perennial grass-annual grass-legume and California poppy mixtures. Two types of perennial grass-annual mixtures were seeded. One was perennial and annual grasses, designed to provide early erosion control by the annual grasses and long-term control by the perennials. The other type was perennial grasses plus clovers and poppy and designed for long-term erosion control, fire control, nitrogen production, and appearance. When 'Blando' brome or 'Wimmera 62' ryegrass was seeded with the perennial grasses at only 8 pounds per acre, numbers of the perennial grasses did not appear significantly reduced. At Glenco, in an area heavily seeded with 'Wimmera 62' ryegrass and 'Palestine' orchardgrass by the U.S. Bureau of Land Management, 'Palestine' orchardgrass survived remarkably well in competition, particularly on the cooler north-facing slopes. 'Blando' brome, however, appears less competitive with perennial grasses than 'Wimmera 62' ryegrass.

When annual grasses were included with perennial grasses at the 8 pound per acre seeding rate ground cover was improved by 15%. Recent perennial mixtures using either 'Luna' pubescent wheatgrass or 'Luna' and 'Palestine' orchardgrass in combination with clovers and poppy are not yet evaluated. Until more is known about longevity it seems a mixture of 'Luna' pubescent wheatgrass and 'Palestine' orchardgrass would be better than either singly.

Photo 15. 'Wimmera 62' ryegrass seeded with 'Luna' pubescent wheatgrass at the rate of 8 pounds per acre, improved the early cover by 15% without retarding establishment of 'Luna.'

Cereal grain-annual grass-legume mixtures. These were tested in the 1972-1973 season at Crystal Springs. Including barley in the mixture did not improve the percentage of soil covered on a cut slope and only slightly increased the cover on a fill slope. For example, on December 30, 1972 the soil covered by a mixture of 'Blando' brome and 'Lana' vetch on a cut slope was 50%, whereas with barley, 'Blando' brome, and 'Lana' vetch it was about 40%. On a fill slope the respective covers were 75% and 85%. The failure of barley to increase the cover was attributed to a reduction in the proportion of grass seed and not enough barley had been added to make up for the reduction of annual grasses. In this case, 10 pounds of 'Blando' brome was replaced by 80 pounds of barley (2,650,000 seeds replaced by only 1,120,000).

Conclusions. The best annual grasses were 'Wimmera 62' ryegrass, annual ryegrass, and 'Blando' brome. Although 'Blando' brome does not grow as fast as the ryegrasses, it provides good soil protection, blends with the natural grassy landscape where it is likely to be a major component, is less likely to yield an unsightly cover, and persists better in dry areas and at lower fertility levels. There has been speculation that endemic species would more quickly invade the sparsely populated old stands of ryegrass than the better ones of 'Blando' brome. This was not noticed but may become apparent as the stands grow older.

Four promising annual grasses now being tested are foxtail fescue, red brome, quakinggrass, and annual bluegrass. Only annual bluegrass has commercial seed sources, and these are limited. Foxtail fescue and red brome have troublesome pointed seeds with slender awns.

Two promising perennial grasses are 'Luna' pubescent wheatgrass and 'Palestine' orchardgrass. These would provide more stable covers with a longer green period and less fuel volume than the annual grasses now in use. 'Hardinggrass' and 'Perla' koleagrass have grown vigorously but both are tall and bunchy, particularly 'Perla' koleagrass.

The better annual legumes are rose clover and 'Lana' vetch. Rose clover does well on shallow cut slopes, and 'Lana' vetch provides a dense vegetative soil cover on deeper soils. 'Lana' vetch is difficult to mow. Birdsfoot trefoil provides greenery and color in the coastal area and in moist places but there are not enough plants to provide a good protective soil cover.

The better annual mixtures are 'Blando' brome and rose clover where the erosion hazard is not high, and 'Wimmera 62' ryegrass and 'Lana' vetch where it is. Red brome has been the best grass with California poppy because it has not been as competitive, has a reddish hue which complements the golden color of the poppy flower, and is short, allowing the poppy flowers to show. Although it has remained on a dry south-facing cut slope at Crystal Springs, it disappeared from the deeper fill areas. This reflects its adaptation to drier climates receiving less than 10 inches average precipitation.

Small amounts of annual grasses have been seeded with perennial grasses without greatly reducing establishment of the perennials. 'Blando' brome appears less competitive than 'Wimmera 62' ryegrass. It is too early for clovers and the California poppy to be evaluated in combination with 'Luna' pubescent wheatgrass and 'Palestine' orchardgrass.

Recommendations. Selected herbaceous seedings made during this study should be monitored for persistence and appearance of the seeded species and for invasion of resident ones, particularly trees and shrubs. Further, large scale seedings are recommended for a more complete evaluation of the better single species and mixtures.

Implementation. The findings are already being used in designing seedings for erosion control. In areas where he has had little experience, the designer can use these results with confidence. Suggested seeding mixtures are included in a separate section at the end of the report titled "Herbaceous Seeding Guide for California by Major Land Resource Areas."

METHODS OF ESTABLISHMENT

Both hydroseeding and the straw mulch procedure presented few difficulties in establishing adapted herbaceous species in areas of new construction at lower elevations. That is not surprising since the lower elevations usually have a long rainy period plus relatively warm weather in late fall and early winter, which are ideal conditions for establishment, particularly of the aggressive annuals. Even so, some problems were encountered: seed and wood-fiber mulch slid down a steep slope that had been graded smooth; soil sloughed out of a poorly compacted steep fill and waters concentrating on pavements and overflowing down fill slopes caused rills and gullying and loss of seed on

two other sites. On one straw covered fill slope straw applied commercially was too thick and heavy for seedlings of most species to penetrate although excellent for erosion control; volunteer barley seed in another straw-covered area competed severely with perennial grasses; and mice were quick to take advantage of straw covers as well as to quickly move into new grass covers, damaging grasses and shrubs and harvesting an unknown amount of volunteer seed from annuals such as ryegrass and 'Lana' vetch.

Wood-fiber mulch might not help establishment when slopes are left rough. In the fall of 1972, two plots on a cut slope and two on a fill were not mulched. The soil was terraced and roughened on the cut and was left rough on the fill. There was no visual difference in

Photo 16. A rough seedbed at one of the Crystal Springs planting sites.

numbers of seedlings or in the amount of soil covered by vegetation as a result of mulching. Mulch did cover and protect the soil, however, and the soil fines lost appeared less than without the mulch. These results were on small (10 x 30 foot) plots. Had the plots been larger, more erosion might have taken place, with loss of seed and poorer establishment. At Crystal Springs a rough seedbed on a large fill slope was seeded and fertilized but was inadvertently left unmulched by the contractor. Excellent stands developed and there was little erosion. The soil material in the fill had a high content of broken rock parent material and was not classed as very erosive.

At the rates recommended by the manufacturer, a soil binder was also mixed with the wood-fiber mulch in seedings made at Cameron Park and Tahoe Basin. Since there was no visual improvement either in plant

establishment or in holding the wood fiber together, this treatment was discontinued.

Mulching with straw gave noticeably better soil protection than did wood-fiber mulch. Also, when seedings were late and it was cold at Cameron Park, the protection of straw gave better growth of seeded grasses than did wood-fiber mulch.

In the fall of 1973, several waterways on Ponderosa Road Overpass, above Cameron Park on U,S. 50, were shaped up, seeded, and fertilized, and a fiberglass roving-asphalt emulsion was applied over the seed. The cover fitted the soil closely, there was no erosion, and grass and legume seedlings easily emerged through it. This Study is reported in Supplementary Study 2.

Conclusions. In numerous trials, adapted grasses and legumes were easily established on weedfree rough seedbeds at lower elevations by hydromulch or straw mulch techniques. Barley straw mulch, although excellent for erosion control, has disadvantages in that volunteer barley from seed in the straw competes with the seeded species; the straw also harbors mice. In more limited trials, good stands were also obtained from seeding on rough seedbeds without mulch. Wood-fiber mulch helped hold soil particles in place until a vegetative cover could be established.

Implementation. Present methods of establishing grasses and legumes at lower elevations were satisfactory on rough seedbeds. Although results were good from seedings made on a rough seedbed without mulch, too few trials were made to say that mulch is not necessary for establishment on all seedbeds. It seems possible that mulch could be eliminated on rough new seedbeds where the soil material is relatively stable.

METHODS OF MAINTENANCE

Aside from mowing for fire hazard reduction, maintenance operations have been minimal on the areas seeded for erosion control. In practice, these areas were seeded with barley or ryegrass only for initial erosion control; that is, a quick vegetative cover was needed to reduce or prevent erosion on the newly disturbed slopes, followed by little or no maintenance of the cover. If the seeded species did not remain on the slope, and it usually did not, it had served its original purpose of initial erosion control, after which naturalized resident species (mainly annual grasses) would be expected to move into the area.

Maintenance operations also have been minimal on old areas that had not been seeded but where volunteer grassy covers developed. Some slopes were too steep, erodible, infertile, or a combination of these, to sustain a protective cover. In such cases fertilizer, particularly nitrogen, could be used to increase growth and maintain a substantial cover. Sometimes, however, the volunteer cover would be so sparse that seeding and also fertilizing would be necessary as part of maintenance operations.

Where low-growing species are desirable for a plant cover, the solution may be to mow out the tall-growing plants.

In this study, trials to maintain the seeded plants or to manipulate the covers has been almost entirely limited to fertilization with nitrogen fertilizer in combination with phosphorus and sulfur. Some mowing was conducted to maintain the California poppy in Special Stxdy 4. The following presents the results of fertilization on new stands of herbaceous species on new slopes and on volunteer stands on old slopes where the soil was eroding.

Fertilizing new stands on new slopes

A maintenance application of ammonium phosphate sulfate 16-20-0 at 200 pounds per acre on established stands increased the growth of annual grasses, usually at the expense of cloyers and the California poppy. Fertilization increased the density of the annual cover up to an estimated 100% and increased heights up to four times. After three years of fertilization, the fertilized areas were dominated by grasses either by crowding out or keeping out broadleaf plants. Perennial grasses appeared to respond less than annuals, and in combination with annuals seemed to give way to them. In dense stands of perennial grasses, however, the annual grasses seemed less able to use the fertilizer to their advantage.

Seeding and fertilizing old slopes that are eroding

Two eroding old cut slopes south of Placerville were seeded, fertilized, and hydromulched with annual grasses and 'Lana' vetch in 1970. These slopes had not been seeded and the vegetative cover was volunteer annual grasses. Both developed good covers from the seeded species plus resident annuals, bare areas were filled with vegetation, the gullies healed over, and erosion was arrested. Four years later, however, the steeper slopes (1:1) began to deteriorate and slump out again in the less stable areas. The lesser slope (1-1/2:1), which had an erosive layer across it, also deteriorated where this layer occurred. In both cases it was evident that fertilization might have to be continued to prevent erosion from recurring.

Photo 17. Erosion was arrested when eroding slopes south of Placerville were seeded, fertilized, and hydromulched with annual grasses and 'Lana' vetch. Before seeding (left); after seeding (right).

Conclusions

Maintenance applications of ammonium phosphate sulfate fertilizer 16-20-0 at 200 pounds per acre increased the growth of annual grasses in particular. Unless the slope is beginning to erode or deteriorate, there is little or no advantage in fertilizing since this increases annual grasses at the expense of clovers, and perhaps even of perennial grasses.

Recommendations

Where old slopes are deteriorating, fertilizing and possibly seeding may be necessary to check further damage. Where this had been done, the bare areas were filled and gullies healed. Slopes can be carefully watched for signs of deterioration and accelerated erosion, whereupon maintanence applications of fertilizer can be made in a planned program of slope stabilization. Stabilization may sometimes

require reseeding in addition to fertilizing. Severely eroded slopes may require extensive repair before reseeding and fertilizing.

Implementation

These recommendations are under consideration by CALTRANS maintenance personnel.

2. TAHOE BASIN AND VICINITY

The Tahoe Basin is a very sensitive area because of the danger of polluting the clear waters of Lake Tahoe and major emphasis has been placed on developing herbaceous species for erosion control on disturbed areas. Considered secondarily was revegetation with shrubby plant material.

The Tahoe Basin lies east of the crest of the Sierra Nevada Mountains in an area where the coniferous forest begins to merge gently with the drier Great Basin flora. The climate, flora, and soils (or parent materials) are generally similar to those of other higher mountainous areas in California with winter snow.

No major test sites were located on state highway rights-of-way in the Basin because no suitable ones existed. Instead, as many as possible were located on slopes at the newly constructed El Dorado County Airport at South Lake Tahoe, on new Nevada state highways, on California state highways out of but in the vicinity of the Basin, on county roads in the Basin in El Dorado and Placer Counties, and in one major resort development project, Northstar at Tahoe. Descriptions of the sites, including exposure, soils, and parent materials are found in Appendix Table 16, page A-19. When possible, test plots were located on both northerly and southerly exposures and upon representative soils. According to a recent soil survey in the Basin, most of the soils are coarse textured and of either andesitic or granitic origin (16).

Although all the soils were coarse textured, they contained some clay at the South Lake Tahoe Airport and at the Northstar at Tahoe development resort. Trials with herbaceous species began in the fall of 1970 and continued into the spring of 1975.

SPECIES ADAPTATION

At higher elevations in the Sierra Nevada, perennial grasses are the main herbaceous species used for erosion control. These develop slowly in comparison with annual grasses at lower elevations.

Single species

Forty-six herbaceous species were evaluated, singly or in combination, in the Tahoe Basin and vicinity. Summaries of success in establishment, reactions in mixtures, and pertinent remarks are found in Appendix Table 17, page A-22.

'Luna' pubescent wheatgrass and 'Tegmar' intermediate wheatgrass have consistently been the better species, followed by 'Fairway' crested wheatgrass on drier sites, and 'Latar' orchardgrass on moist sites. 'Sherman' big bluegrass and, to a lesser extent, 'Durar' hard fescue have had successes. 'Manchar' smooth brome has added color in mixtures. These perennial grasses and cicer milkvetch are described separately below.

'Luna' pubescent wheatgrass. 'Luna' pubescent wheatgrass shows more seedling vigor than the other grasses and, except for 'Tegmar' intermediate wheatgrass, has established better on droughty or otherwise difficult sites. 'Luna' is rhizomatous and matures early (at about 24 inches).

'Tegmar' intermediate wheatgrass. 'Tegmar' intermediate wheatgrass is slightly inferior to 'Luna' pubescent wheatgrass in establishment but superior to 'Greenar' intermediate wheatgrass. It could be substituted for 'Luna' pubescent wheatgrass. 'Tegmar' intermediate wheatgrass is rhizomatous, stays green longer and is shorter than 'Luna.'

'Fairway' crested wheatgrass. 'Fairway' crested wheatgrass is an early maturing medium-tall, long-lived bunchgrass. It did not compete well with 'Luna' or 'Tegmar' except on droughty sites.

'Latar' orchardgrass. 'Latar' orchardgrass is a late-maturing tall, long-lived bunchgrass. 'Latar' orchardgrass does not compete strongly with 'Luna' pubescent wheatgrass or 'Tegmar' intermediate wheatgrass, but on one moist site it equaled the two wheatgrasses in growth.

'Sherman' big bluegrass. 'Sherman' big bluegrass is a blue-colored

Photo 18. From left to right are 'Luna' pubescent wheatgrass, 'Sherman' big bluegrass, 'Fairway' crested wheatgrass, 'Latar' orchardgrass, 'Durar' hard fescue, and 'Tegmar' intermediate wheatgrass.

early-maturing fine leaved bunchgrass. It grows well in mixtures, breaking up the solid appearance of single-species planting.

'Manchar' smooth brome. 'Manchar' smooth brome, a rhizomatous grass, was rated fair in establishment. 'Manchar' smooth brome has deep green foliage and broad brown seedheads which add color and contrast to mixtures with the above grasses.

Other promising perennial grass strains not fully tested in this study were 'Oahe' intermediate wheatgrass and 'Potomac' orchardgrass.

Three short-growing grasses in trials are 'Pomar' orchardgrass, 'Sodar' streambank wheatgrass, and 'Durar' hard fescue. They grew well together on less erodible sites at the El Dorado County Airport.

Photo 19. Three short growing grasses 'Pomar' orchardgrass, 'Sodar' streambank wheatgrass, and 'Durar' hard fescue, in combination on one of the better sites at the El Dorado County Airport, South Lake Tahoe.

No satisfactory stands of a perennial legume were established quickly or consistently, although some cicer milkvetch plants spread and provided good soil coverage.

'Cicar' cicer milkvetch. The 'Cicar' variety was used except late in the study when 'Lutana' was seeded. This rhizomatous spreading legume develops slowly but becomes as tall as 'Luna' pubescent wheatgrass upon reaching maturity. It flowers profusely on moist areas, adding color to a mixture. Other perennial legumes being tested are 'Rambler' alfalfa, 'Cascade' and narrowleaf birdsfoot trefoils, and white 'Dutch' clover. Alfalfa is objectionable because it is highly palatable to foraging animals. The birdsfoot

trefoils grew and flowered profusely in moist areas, adding greenery and color to a mixture. White 'Dutch' clover grows fairly well in short-grass mixtures on finer textured soils with good moisture-holding capacity.

Photo 20. Though difficult to establish cicer milkvetch plants spread and provide good soil coverage on andesitic soil at Lake Tahoe.

Annual grasses and cereals. The Mediterranean-type annual grasses grow rather poorly in high, cold elevations. 'Blando' brome perpetuated itself in a mixture for 4 years at Alturas but failed in the Tahoe Basin. 'Wimmera 62' ryegrass, red brome, and foxtail fescue also failed after the first year. Cereal rye is the most aggressive cereal grain tested. It did not become weedy in the Basin.

Mixtures of grasses and legumes

Sixteen mixtures of grasses and legumes were seeded from 1970 to 1974. These are listed in Appendix Table 18, page A-27. 'Luna' pubescent wheatgrass and 'Tegmar' intermediate wheatgrass usually dominated mixtures in which either one or both were seeded. This might have been expected since these were consistently the stronger species in single-species trials. Other grasses and legumes of secondary importance sometimes made up substantial parts of mixtures, although legumes in particular were erratic, probably because they were not well

Photo 21. 'Luna' pubescent and 'Tegmar' intermediate wheatgrasses dominate grass mixtures in the Tahoe Basin.

adapted to the drier conditions in the Basin. 'Sherman' big bluegrass competed well with 'Luna' pubescent wheatgrass and 'Tegmar' intermediate wheatgrass, at times making up to 50% of the mixture. 'Durar' hard fescue dominated the mixture on a compacted fill, while 'Fairway' crested wheatgrass, 'Sodar' streambank wheatgrass, 'Latar' orchardgrass, and 'Manchar' smooth brome seldom made up 10% of the total coverage in a mixture. The legumes, cicer milkvetch, 'Rambler' alfalfa, and yellow blossom sweet clover were more prevalent in mixtures where moisture conditions were better. They also favored the finer textured glacial or volcanic soils. Under these conditions, cicer milkvetch and 'Rambler' alfalfa, with their wide-spreading crowns, made up to 75% of the vegetative cover, but such instances occurred less than 5% of the time. Yellow blossom sweet clover did not present the tall growth and competition problem expected, probably because of the dry conditions. 'Cascade' and narrowleaf trefoils added colorful flowers and greenery to mixtures in moist areas. 'Blando' brome and 'Wimmera 62' ryegrass grew poorly in mixtures. Cereal rye grew vigorously in mixtures but allowed some perennial grass to survive; such a mixture has not been adequately evaluated.

Conclusions

Of the 46 herbaceous species evaluated, singly or in mixtures in the Tahoe Basin, 'Luna' pubescent wheatgrass and 'Tegmar' intermediate wheatgrass were consistently outstanding. Of secondary importance were 'Sherman' big bluegrass, 'Durar' hard fescue, and 'Fairway' crested

wheatgrass on drier sites, and 'Latar' orchardgrass on more moist sites. Two grasses tested less completely but considered appropriate substitutes were 'Oahe' intermediate wheatgrass for 'Tegmar' intermediate wheatgrass and 'Potomac' orchardgrass for 'Latar' orchardgrass. Cicer milkvetch has been the better legume. Although it established poorly, it made substantial contributions to ground covers by the third year, spreading by rhizomes on moist areas and on some finer textured glacial or volcanic soils. Volunteer seedlings were also noted. 'Blando' brome and 'Wimmera 62' ryegrass did poorly when seeded singly or in mixtures. Two other Mediterannean annual grasses, red brome and foxtail fescue, performed poorly.

Recommendations

'Luna' pubescent wheatgrass and 'Tegmar' intermediate wheatgrass, along with the other species mentioned above, are recommended for the Tahoe Basin and similar mountainous areas. Although cicer milkvetch is slow to establish, it is persistent and should be included in a mixture to add color and to provide a source of nitrogen that would enhance grass growth.

Implementation

These species are being used in seeding recommendations by CALTRANS. They provide erosion control designers with species of known value and eliminate species of unknown or questionable performance.

METHODS OF ESTABLISHMENT

Effective cover requires good stand establishment. Anything less will waste valuable seed, time, and money while failing to achieve the purpose of the seeding. Even well-adapted species can fail unless the seedbed is good and the seeding is carried out by prescribed procedures. If establishment fails, then, instead of providing an effective vegetative cover, perhaps for years to come, the cover is of poor quality, only partially effective and possibly a fire hazard. In construction work, erosion control seeding can be designed from known facts with fairly accurate prediction of success, allowing for vagaries of the weather.

In this modified continental climatic zone the seed must be kept in contact with moisture long enough to germinate and for the seedling to become established. The best place for seed is within the soil, in reach of moisture, and out of reach of drying winds. Many wild species, however, germinate in small depressions where a good bond forms between the seed and the soil. This is why seedbeds should be rough. Fortunately, soil crusting on the surface was not a problem in these studies as it has been in range reseeding, mainly because the disturbed material is coarse textured with little or no clay.

Seedling establishment and persistence

Table 1 shows the average number of seedlings per square foot of grasses and legumes seeded in mixtures using wood-fiber mulch and hydromulching, with variations between locations in fall and spring seedings. The differences in numbers of seedlings between locations, in both fall or spring seedings were doubtless due to differences in soil, exposure, and seedbed conditions. The range was not great, however: 5-9 in fall seedings, and 10-32 in spring. The difference in numbers between fall and spring was almost three times in favor of spring seedings. That is not a critical difference, however, since the numbers in fall were more than adequate to make good stands of grasses. By the fourth year the numbers had decreased at all locations and were about equal except above Glenbrook. Here the plants stayed in better, probably because the soil was more fertile. Those seedings were made during a year when there was good rainfall in April and May and all seedings were generally good. In the next 3 years there was little rain in May and the seedings were poor or failures. This emphasizes the likelihood that hydromulch seedings made at higher elevations will fail. In comparison, as discussed later, good stands developed whenever the seeds were placed in the soil. During these years, also with some exceptions, fair stands developed under a straw mulch when the seed fell into small openings in the soil made by punching in the straw. The important thing appears to be to get the seed into the soil by drilling, incorporating it into the soil with the straw, or by hand planting it into contour furrows.

Seedling numbers generally decreased by years, up to the fourth year at least, although those with rhizomes are expected to begin increasing through underground spread. Actually, a 6- to 8-year-old seeding of intermediate and pubescent wheatgrass at Cave Rock had an estimated 6 to 8 plants per square foot, possibly as a result of rhizomatous activity but still indicative of the number of plants that might be eventually found on a fairly good soil.

Percent soil covered

Table 1 shows the percentage of soil covered was less than 1% the first year in most seedings of perennials. Thus, stands of perennial grasses develop slowly at higher, colder elevations. Since they provide little soil protection the first year, mulching erosive slopes with straw should be considered. By the second year, the plants had grown considerably, increasing soil coverage of better stands to about 18%. For some reason there was little increase or decrease in soil coverage in the third year, but that was followed by a general increase in the fourth year. The decrease in soil coverage in spring seedings at the terminal and the northwest side of the airport was due to frost heaving the plants out of the soil.

In comparison, aggressive annual grasses at lower elevations would cover 80-100% of the soil by the time the perennials at higher elevations began to germinate in the spring.

Table 1. The average number of grasses and percent soil covered by vegetation from 1971-1974 after hydromulching during a favorable season for establishment in the Tahoe Basin. 1/

	Plants per square foot				Percent soil covered			
	1971	1972	1973	1974	1971	1972	1973	1974
Fall 1970								
Terminal	8	6	3	2	1-	16	25	40
NW Airport	5	6	5	1	1-	7	6	10
Above Glenbrook	9	2	0.4	0.1	1-	2	1-	4
Guard station (Spooner)	6	12	5	7	1-	14	12	23
Total	28	26	13.4	9.1		39	44	77
Average	7	6.5	3.4	2.3	1-	10	11	19
Spring 1971								
Terminal	32	9	4	2	1-	18	4	15
NW Airport	28	9	7	3	1-	17	11	15
Above Glenbrook	10	5	2	1	1-	4	2	7
Guard station (Spooner)	11	7	4	4	1-	18	15	43
Total	81	30	17	10		57	32	80
Average	20	7.5	4.3	2.5	1-	14	8	20

1/ The 1972 spring rains were favorable for germination and establishment of grasses seeded in the fall of 1971 and the spring of 1972.

Soils and exposures

The coarseness of higher elevation mountain soils has already been mentioned in relation to plant establishment, i.e., mountain soils are usually close to the igneous material from which they are derived. Being coarse textured, they are usually droughty, and dry quickly when exposed to the sun. Andesitic and basaltic materials are finer textured than granitic, do not dry as quickly, and therefore, are better soils for germination, establishment, and growth. Exposure, too, affects establishment. North-facing slopes are usually more favorable than south-facing ones because they are not exposed as directly or as long to the hot sun, and therefore, hold moisture longer. At Northstar, good stands of grasses developed on a north-facing cut while only a few grasses were found on the south-facing slope across the road.

Problems of establishment

Establishment of grasses and legumes by the hydromulch method of seeding with wood-fiber mulch has not been nearly as good at higher as at lower elevations. Getting both good and bad results without knowing the reasons has been confusing. Some of the reasons were known, such as frost heaving and loss of seed and wood-fiber mulch through slipping off steep slopes, but there seemed to be others. In this phase of the study, the hydromulch method was emphasized as easy to use, but straw mulch was also applied on almost every site. The early results indicated some problems that had previously been perhaps only vaguely apparent. These results also provided some basis for further lines of exploration toward better establishment.

The first fall and winter seedings were successful, but those made afterward often failed except when the soil surface was mulched with straw. When seed was placed within the soil, the seedings were always successful. One reason for poor results was the rapid drying of the soil surface after snowmelt, within a few days or even a few hours in some instances. Seed broadcast on the soil surface, even with wood-fiber mulch, did not have time to germinate before drying unless the soil stayed moist, as in protected areas or seepages or during moist weather. Rapid drying of the surface soil could prevent germination of seed, but other conditions also could reduce germination or subsequent establishment.

Another common problem was incipient germination and loss of seedlings to cold or frost heaving between fluctuating snow covers. This is frequent on the eastern and southern sides of the Basin where slopes are exposed more to the sun and there is less snow. In one instance when snow melted from a south-facing slope near Glenbrook in February, some seeds germinated but the tender seedlings were killed by subsequent freezing temperatures. On an east-facing windswept cut at the Airport, 'Luna' pubescent wheatgrass seed was gathered from the soil surface and a germination test made. In that trial 82% of the seed did not yield plants, either because the seed had germinated (23%) and died during the winter or early spring or for unknown reasons.

Slope conditions which also hampered germination and establishment were coarse textured soils, steepness, eroded surfaces, and weeds. One problem in mountainous areas is the coarseness of soil texture. Although andesitic or basaltic parent materials are finer textured than are granitic, they are still usually coarser than soil material at lower elevations. Coarse-textured soils do not hold much moisture and the rapid drying of the soil surface is partially accounted for by their droughtiness.

On slopes steeper than the angle of repose (about 1-1/2 to 1), seed and mulch slide off in winter unless the slope is of rock or cohesive loose material. Many of the old slopes, being steeper than this, are almost impossible to revegetate without preliminary stabilization by physical means, such as wattling. Eroded slopes present a harsh environment for seeds, in that the soils are compact and the seed forms a poor bond with the soil which dries quickly when exposed to the sun or wind. Old slopes are commonly eroded, often compact, and usually infertile. On old weedy slopes the weeds quickly take advantage of the fertilizer, competing with the small seedling grasses or legumes. To help get good establishment, old slopes or new compact slopes should be loosened with equipment such as a harrow. On deeply eroded slopes, if not too steep, the best way of loosening the surface and smoothing out the gullies would probably be with a bulldozer. To help overcome problems in establishment, several techniques were tested.

New establishment techniques

Mulch trials. Seedings in the fall of 1971 with wood-fiber mulch had poor germination since little rain fell in the following spring. In the fall of 1972, several seeding techniques (Table 2) were compared at South Lake Tahoe Airport. The spring of 1973 was also dry, giving poor stands. Increasing mulch from 1,500 to 3,000 pounds per acre helped germination and seedling emergence, as did doubling the seeding rate to 80 pounds per acre. Doubling both seed and mulch rates brought about a further increase. Mulching the surface with straw, whether punched in or held down with a net, or punched in and seeded before or after mulching, resulted in about six times as many seedlings as did wood-fiber mulch. Results were best with seeds placed in the soil in contour furrows, i.e., 16 plants per lineal foot at 18-inch contour spacing. If all the seed had been placed in contour furrows or drilled, the results would have been good stands instead of near failures. As expected, it was almost useless to throw seed and fertilizer on the soil surface.

Table 2. The average number of seedlings per square foot in the establishment year from various seeding techniques in the Tahoe Basin and vicinity.

Seeding treatment*	Seedlings per square foot
Fall 1972	
1. Broadcast seed, then hydromulch with fertilizer in slurry.	1
2. Hydromulch with seed and fertilizer in slurry	1.3
3. Broadcast seed and fertilizer, no mulch	0.2
4. Broadcast seed, no mulch	0.1
5. Straw mulch tucked by hand with a spade after seeding and fertilizing	7
6. Straw mulch tucked by hand with a spade before seeding and fertilizing	6
7. Straw mulch covered with fiber yarn netting after seeding and fertilizing	6
8. 3,000 lbs of wood-fiber mulch	1.6
9. 80 lbs of seed instead of 40 lbs	1.5
10. 3,000 lbs of wood-fiber and 80 lbs of seed	3.6
11. Seeding and fertilizing in contour furrow 1-inch deep	14 per lineal ft.
Fall 1973	
12. Manure over seed and fertilizer	1
13. Manure and straw over seed and fertilizer	0.5
14. Seed and fertilizer over two inches of topsoil	2

*Unless otherwise indicated, the rates per acre were: seed - 40 lbs; wood-fiber mulch - 1,500 lbs; fertilizer, ammonium phosphate sulfate 16-20-0 - 250 lbs; and straw - 2 tons.

Photo 22. Results were best with seeds placed in the soil in contact with soil moisture on droughty granitic soils at the El Dorado County Airport, South Lake Tahoe.

In the fall of 1973, three treatments (manure, straw, and topsoil) were tried, but another dry spring gave poor results again. There were twice as many plants in the area topsoiled, and they were noticeably larger.

A mixture of bark and woodchips was also used as a mulch in the fall of 1971. On a 3:1 slope, the bark mulch reduced erosion greatly. The bark-woodchip mixtures were tested at 15 and 30 tons per acre. Estimated seedling numbers were lower with the 30-ton rate, indicating some inhibition of emergence by the heavy application. The numbers of seedlings in the 15-ton application were greater than those mulched with wood-fiber or straw as might have been expected as the woodchips tightly blanketed and protected the soil from exposure and erosion.

Hydromulch seeding was effective as long as the soil surface remained moist enough in the spring for the seeds to germinate; otherwise the seedings failed. When spring rains were extensive enough to keep the soil surface moist or snowmelt provided the necessary moisture, good stands developed. Shade from trees also helped keep the soil surface moist. Finer textured soils held soil moisture longer than did coarse textured soils,

Pilot irrigation trial. A pilot irrigation trial was conducted on a fill slope south of the terminal to help establish grasses in the fall. The soil was first thoroughly wet to a depth of 6 inches, seed was broadcast on the soil surface, the soil was mulched with wheat straw at 1 and 2 tons per acre, and the straw was punched into the soil with a garden spade. Irrigation water was applied with

a spray nozzle attached to a garden hose, The irrigation cycle was about every 3 days for 2 weeks,

The treatments were:

1)	Planted August 26, 1971, and irrigated;	1 ton straw
2)	Planted September 30, 1971, and irrigated;	2 tons straw
3)	Planted August 26, 1971, and not irrigated;	1 ton straw

Irrigation in August and September did not result in effective plant covers during that year, A few vigorous volunteer cereal wheat plus some wheatgrass seedlings in rills and spademarks were found in the plot irrigated in September, whereas the unirrigated plot had none because there had been no rain.

Although an effective plant cover did not result in the first year from irrigation (using the 3-day irrigation cycle after seeding in August and September), the plants that started to grow were larger the second year. By summer, soil coverage was 20% for the August irrigated plot, 12% for the September, and 4% for the plot seeded in August but not irrigated. By the third year, however, all treatments had about 35% cover, with no differences observed.

This trial indicates two factors important to designing a new irrigation trial for germinating plants in late summer and early fall: 1) apparently, the 3-day irrigation interval did not keep the seed on the soil surface moist enough for effective germination, although seed germinated in rills where the soil was more moist and in the soil in punchmarks made by the spade, and 2) the rate that water was applied from a spray nozzle attached to a garden hose was too severe, causing soil erosion by rilling, even when protected by a straw mulch. Another alternative is to seed and start irrigation earlier.

Conclusions

Hydromulch seedings with wood-fiber mulch have not been as successful at higher elevations as at lower elevations mainly because the higher soils are coarse textured and droughty and moist periods in the spring were seldom long enough to allow the seed to germinate before drying.

Hydromulch seedings were successful in areas where soil stayed moist, as on northwest-facing exposures, in tree shade, and on slopes that stay moist from seepage. Success was also greater on finer textured soils (such as those derived from basaltic or andesitic rock) than on coarse-textured ones (from granitic rock). When the seed was placed in the soil, however, successful grass stands developed. Establishment was usually better with straw mulch than with wood-fiber mulch. Establishment was also improved when a shallow surface layer of finer textured soil was spread over coarse textured soil. Establishment was improved a little by increasing the amount of wood-fiber. In almost every seeding, whether a success or a failure, some grasses or legumes survived and improved the vegetative cover.

Recommendations

Before seedings are made, slope conditions such as the soil, exposure, steepness, etc., should be carefully evaluated to determine the best method of seeding.

Implementation

The results of this Study are being considered by CALTRANS in designing future erosion control seedings in mountainous areas.

METHODS OF MAINTENANCE

Maintenance trials included: 1) fertilizing slopes where herbaceous covers developed from recent seedings, and 2) seeding and fertilizing old slopes with only sparse herbaceous vegetation.

At the airport terminal, half the areas in two recent seedings were fertilized with ammonium phosphate sulfate fertilizer 16-20-0 at 200 pounds per acre in the spring of 1974. Plants on the fill slope had little response, increasing the ground cover only from 40% to 45%. Fertilizer possibly had little apparent effect because fertility was already fairly high in the fill soil. On the cut slope the effect of fertilizer was more pronounced, the ground cover increased from 20% to 40%, and average grass height increased from 10 to 14 inches. On the cut slope fertilizer not only increased plant growth but also made the plants bigger and stronger so they were able to resist frost heaving.

Along Pioneer Trail, 11 old slopes were hydromulch-seeded with varying success. There was little establishment on slopes steeper than 1.5:1 because seed and mulch slid down the slope along with the eroding material. On a slope a little steeper than 1.5:1, in fine-textured, more cohesive soil, as many as six grasses per square foot were established. Success still varied, however, on the more gentle slopes. Seedling establishment was greater where the soil was finer textured or shaded, and less on coarse textured or exposed sites.

Near Incline Village, at the request of the Nevada Division of Highways, a particularly bare portion of a fill slope was reseeded and fertilized in the spring of 1971. It had been hydromulch seeded in 1968 with very poor results. The slope was composed of loose granitic material plus some large rocks which helped stabilize the slope. After the second seeding in 1971, ground cover increased to 50% by 1974 (40% from seeded species and 10% from cheatgrass already on the slope).

Conclusions

Maintenance applications of ammonium phosphate sulfate fertilizer 16-20-0 at 200 pounds per acre may increase ground cover substantially on slopes of low fertility. On a cut slope of low fertility, ground cover was increased from 20% to 40% by fertilizing. On a fill slope,

ground cover was increased from 40% to 45% (only 5 percentage points) possibly because fertility was higher so the growth response did not appear as great.

Old slopes needing better cover can sometimes be improved by hydromulch seeding and fertilizing if they are less steep than 1.5:1 or if the slopes are somewhat steeper but the soil more cohesive. More grasses were established on fine-textured or shaded soils and less on coarse-textured or exposed soils.

Recommendations

It is recommended that scant or deteriorating herbaceous plant covers be fertilized or hydromulch-seeded and fertilized to improve vegetative cover if they are less steep than 1.5:1. To improve establishment, their surfaces should be roughed up and existing rills and gullies filled in.

Implementation

A successful maintenance seeding was made on an old loose granitic slope at Incline Village at the request of the Nevada Department of Highways.

3. ALTURAS

The species evaluated at Alturas were the same as in the Tahoe Basin. Both are in the modified continental zone and the climates are similar except that precipitation is much less at Alturas. The species are listed in Table 4 located in the section regarding the Tahoe Basin. Three fall and three spring seedings were made on an area of new construction south of Alturas. In the cut areas the soils were shallow and droughty and all seedings would have been considered failures except that some of the better grasses consistently became established.

SPECIES ADAPTATION

Perennial grasses. Consistently the better perennial grasses at Alturas, seeded singly and in mixtures, were 'Fairway' crested wheatgrass, 'Luna' pubescent wheatgrass, 'Tegmar' intermediate wheatgrass, and 'Sherman' big bluegrass. This was true on both cut and fill slopes, although the soils on the cut slopes were very shallow and droughty and few plants became established. 'Fairway' crested wheatgrass was superior to the others. 'Oahe' intermediate wheatgrass, one of the popular species used in range reseeding at Alturas, seemed promising in later trials.

Table 3 gives the number of seedlings per square foot and percent soil covered for these grasses in the establishment year (1972) and 2 years later (1974). Data for other years were from seedings made in the cut area only. They are not listed but were similar to the data for 1972. Plants of 'Luna' pubescent wheatgrass and 'Fairway'

Photo 23. A stand of perennial grasses on a fill slope at Alturas.

crested wheatgrass were the highest of all grasses in the establishment year and 3 years later. Soil coverage by all species was negligible in the establishment year (less than 1%). In 1974 the highest coverage on the cut was 6% (for 'Luna' pubescent wheatgrass and 'Fairway' crested wheatgrass) and on the fill was 25% (for 'Fairway' crested wheatgrass; 'Tegmar' intermediate wheatgrass was 15%). There were 6 times as many plants on the fill as on the cut in the beginning and 5 times as many 3 years later. While ground coverage was originally less than 1% on both cut and fill, it later became 3 times as great on the fill. The better showing on the fill could be expected since fill soils are deeper and usually better, but the margin of difference was greater than usual because of the poor quality of the soils on the cut slopes.

Table 3. The average number of seedlings per square foot and percent soil covered in 1972 1/ and 1974 by four promising grasses for erosion control at Alturas.

Species	Seedlings per ft.^{2}				Percent soil covered			
	Cut		Fill		Cut		Fill	
	1972	1974	1972	1974	1972	1974	1972	1974
'Luna'pubescent wheatgrass	1.0	0.5	4.0	1.5	1-	6	1-	5
'Tegmar' intermediate wheatgrass	0.7	0.3	2.0	2	1-	3	1-	15
'Fairway' crested wheatgrass	1.1	0.5	8.0	3	1-	6	1-	25
'Sherman' big bluegrass	0.5	0.1	5.0	1	1-	2	1-	10

1/ 1972 was the first year after seeding or the establishment year.

Perennial legumes. 'Rambler' alfalfa, cicer milkvetch, and yellow blossom sweet clover germinated, but they failed because of the droughty climate and soil conditions.

Annual grasses, cereal grains, and weeds. Several annual grasses from the Mediterranean-type climate were established but failed to persist. 'Blando' brome persisted for 4 years, providing considerable ground cover in the first and second years on fill slopes in a mixture specified by CALTRANS and seeded by contract. This area was straw mulched and seed fell into the punch holes made by the straw puncher. 'Blando' brome grew poorly on cut slopes seeded in this study. Cereal rye grew well on the cut slopes the first year after seeding but failed to persist. Cereal rye was superior to barley. Plants of cheatgrass, a weedy but naturalized exotic annual grass, took advantage of the fertilizer and grew to about ten times their usual height on the upper parts of cut slopes where the soil was deeper. Volunteer mustard plants also thrived on the fertilizer and provided protection to the soil.

Soils and exposures

Both the cut slopes and the fill slopes were mainly from Warm Springs Tuff, a droughty volcanic soil material over which developed the Casuse loam soil series. Although the fill area passed over several miles of marshy soil, the fill material in the roadbed was mainly tuff from the cut area. Establishment and growth of grasses were very poor on the shallow gravelly cuts but were good on the broken-up material used in fills. There seemed little difference in species adaptation to cut slopes or to fill slopes, or to north or south-facing exposures.

Photo 24. Seeded grasses grew poorly on shallow gravelly cut slopes, but volunteer cheatgrass and mustard flourished when fertilizer was applied.

Conclusions

The better grasses in the trials at Alturas were 'Fairway' crested wheatgrass, 'Luna' pubescent wheatgrass, 'Tegmar' intermediate wheatgrass, and 'Sherman' big bluegrass, with the first superior to the other three. No legume proved satisfactory. Cereal rye developed rapidly in the first year making a substantial plant cover. 'Blando' brome grew well in mixtures with perennial grasses on fill slopes mulched with straw. It did poorly on shallow cut slopes. Volunteer weedy species such as cheatgrass and mustard took advantage of the fertilizer and provided soil protection on the cut slopes.

Recommendations

Use the four perennial grasses listed in "Conclusions."

Implementation

These results are already being used by CALTRANS.

METHODS OF ESTABLISHMENT

Several techniques were tested to improve stand establishment under the droughty soil and climatic conditions at Alturas. Similar to the results in the Tahoe Basin on coarse granitic soils, seed placed

on the surface often dried before it could germinate and small seedlings died before they were rooted. Establishment was improved when the seed was placed into the soil, either in small furrows or by hydroseeding the seed into depressions in the soil made by a straw puncher. Since the soil was coarse textured, crusting did not occur and seedlings easily emerged, even from considerable depths. To increase survival, in the fall of 1972 seeding rates were increased, the rate of wood-fiber mulch was increased, topsoil was spread 2 inches deep over the soil surface, and manure and straw were spread on the soil surface. The following spring and summer were very droughty, and although seedling numbers differed in the spring, by fall the plants were dead and so closely eaten by rabbits that the treatments could not be evaluated.

Photo 25. Establishment was improved by broadcasting the seed into depressions in the soil while punching in straw.

The seeding made by contract in the fall of 1971 was better than that made in the SCS study. The superiority was attributed mainly to the seed falling into depressions made by the straw puncher. Where this occurred, seedlings numbered about 12 per square foot. In certain local areas, however, the straw was so thick that few seedlings could emerge through the layer. This thickness measured 2 inches after passing through one winter and summer so that it was at least 3 inches thick when applied.

Conclusions

Placing the seed within the soil probably outweighs any other technique in getting plants established. This can be done by drilling, broadcasting seed into depressions made by a commercial straw puncher,

or broadcasting seed into depressions made by tractor cleats. A minimum treatment would be a rough seedbed.

METHODS OF MAINTENANCE

In the spring of 1972, areas in two cuts and two fills on the old highway south of Alturas were hydromulch seeded and fertilized. The soil series was Delma sandy loam. The parent material was soft plio-pleistocene lake deposits. The cuts were windswept, bare, and eroding. The seed mixture was 'Topar' pubescent wheatgrass, 'Fairway' crested wheatgrass, 'Sherman' big bluegrass, 'Latar' orchardgrass, and cicer milkvetch. In 1974, about 50% of the soil on the cut area was covered by 'Fairway' wheatgrass, 'Topar' pubescent wheatgrass, 'Sherman' big bluegrass, and weeds (taking advantage of the fertilizer). Grass numbers, about three per square foot, were equally divided among the three grasses. Although plants started on the fill slopes, the area was in the highway firestrip and the plants were killed by herbicide sprays.

Photo 26. At Alturas, perennial grasses were started on an eroding old highway slope by the hydromulch seeding method during a favorable year. The seeded plot (left) has about 50% of the soil covered by vegetation.

Conclusions

Grasses can be started on eroding old highway slopes by the hydromulch seeding method if seedbed and climate are favorable. The seeded annual grasses and resident weeds may combine to make an effective ground cover.

Recommendations

Revegetation should be considered for eroding old highway slopes.

Implementation

These results are being considered by CALTRANS personnel.

IV. SHRUBS FOR REVEGETATION AND GENERAL LANDSCAPE USE

Shrubs for landscaping have been planted along highways and in downtown and suburban areas for many years. They have been irrigated and maintained carefully. In recent years, there has been a desire to revegetate the highway rights-of-way with native vegetation in semi-urban and rural areas. This requires establishment of native vegetation. Reduction of irrigation costs calls for the use of more drought-tolerant native or exotic shrubs for screens and bank covers. Shrubs for screens should grow 6 feet tall within a maximum of 3 years. Those for bank covers should be less than 5 feet tall, wide-spreading, rapid growing, and easy to maintain.

Shrubs also provide erosion control, particularly long term. At the start they are not efficient, but when they form a closed canopy over the soil and duff accumulates, shrubs become very effective. In addition, the deep wide-spreading root systems binds the surface soil mantle together, preventing small shallow slips on steep sloping lands.

Photo 27. When native shrubs were removed the widespread root systems of shrubs were destroyed and small shallow slips occurred on steep sloping land. This points out the long term importance of shrubs for erosion control.

The areas of priority for testing shrubs were the same as for herbaceous species: north-central coastal and Sierra Nevada foothills, Tahoe Basin, and Alturas. Emphasis was greater on the foothills than on Tahoe Basin and Alturas. Emphasis was reduced in the Tahoe Basin because U.C. Davis was already studying native shrub establishment there. To avoid

overlap with Davis, shrubs in this study were limited to exotics, though native shrubs were used as a check against the exotics. A limited amount of native species were also studied outside the Basin. Shrub testing at Alturas was limited to seeding shrubs, not only because the area is droughty and container-grown shrubs would be difficult to establish but also because there is not an extensive need for shrub plantings there.

Although this section of the report deals with tests of shrubs in designated priority areas, native shrubs and trees for consideration in revegetation are listed by Major Land Resource Areas at the end of the report.

Two segments of the shrub section are considered separately for different reasons: 1) "Woody Plant Propagation" was a comprehensive section written separately by Jack Carlson, who propagated most shrubs during the last 2 years of the Project, and 2) the segment on "Bare-root Propagation and Establishment of Native Shrubs" was originally designated as a separate study.

METHODS OF ESTABLISHMENT AND MAINTENANCE

METHODS OF ESTABLISHMENT

Selection of shrubs

Plants were selected for evaluation on the basis of expected adaptability and availability from four sources: 1) promising species selected from those in initial trials in the woody block at Pleasanton PMC, 2) promising plants sought from other organizations or private concerns, 3) promising plants requested from the U.S.D.A. Plant Introduction Station, Beltsville, Maryland, and 4) promising native plants selected from the wild. Native plants were originally selected on the basis of a wide distribution, with later additions of some narrow endemics and naturally occurring Ceanothus hybrids.

Collection of plant material for propagation

Plant material was obtained by three methods: 1) seeds or cuttings were obtained from the Pleasanton and Lockeford or other Plant Materials Centers, from wild plants, or from other testing agencies, such as the Fire Laboratory of the U.S. Forest Service, Riverside, California, 2) plants and seed were bought from commercial sources, and 3) wild seedlings (wildlings) were carefully collected.

Propagation

One of the most difficult problems encountered was propagation of native shrubs in quantity soon enough for transplanting. The study was faced with such questions as whether to use cuttings or seed; what kind of cuttings, and when to collect them; how to root them; how to collect or obtain seed; how to treat the seed; and when and how to plant it. Fortunately, several governmental agencies and private concerns had been propagating wild shrubs from seed for many years, so helpful information was available. Before it could be used, however, this information usually had to be evaluated, tested, and sometimes refined. The propagation of shrubby plant materials of container-grown stock is well outlined in the section on "Woody Plant Propagation."

Establishment

Plant materials. The establishment studies used three types of plant materials: container-grown plants, bareroot stock, and plants grown in the field from direct seeding. The first year, plants were established as container-grown material in gallon cans. Used in the second, third, and fourth years were gallon cans and tarpaper bands. The tarpaper bands were mostly size 2-3/4 x 2-3/4 x 8 inches or 1-3/4 x 1-3/4 x 6 inches. Tested in the fourth year were some innovations in plastic and paper containers. Bare-root material was either

stock grown at the Plant Materials Center or "wildlings." This type of stock is elaborated on in the portion of the report devoted to bare-root material.

Several ways of establishing shrubs from direct seeding were tested: 1) seed was placed in shallow furrows, 2) seed was broadcast on the soil surface and covered with mulch, and 3) dormant seed was brought in with topsoil that was gathered from around shrubs and then spread over the soil surface about 1.5 inches deep.

Site selection. Whenever possible, slopes through representative soils were used. New slopes were preferred because they were not eroded or weedy. When old slopes were used, any weeds present were removed either by hoeing or by applying herbicidal sprays such as Paraquat and Sinox.

Fertilizing. The seedlings were fertilized with 0.29 ounce each of nitrogen, phosphate, and potassium, all in a slow-release form. The fertilizer was placed in the bottom few inches of backfill, below the roots of the transplants. Simple fertilizer trials were conducted to determine the effects of fertilizer (particularly nitrogen) on plant establishment. These trials are described under "Results."

Planting procedure. Container-grown materials were planted in holes 12-14 inches deep excavated with bucket-type post hole diggers for gallon-can stock, or with a four-inch power auger for stock grown in smaller containers such as tarpaper bands. In the last two planting seasons, the holes were bored more perpendicular to the slope than vertical. This minimized soil surface disturbance, also, debris was more likely to slide under or by the plants without burying them when they were positioned more at right angles to the surface. This technique also placed the roots deeper into soil moisture.

The transplant was carefully positioned approximately parallel to the axis of the planting hole with the crown level with the soil surface. The hole was carefully backfilled and the soil firmed around the roots to remove air pockets. If the soil was too dry, water was applied to moisten and help firm the backfill. To insure lateral root extension, at least two sides of the tarpaper bands were removed before planting.

Postplanting activities in the establishment year

Postplanting activities during the establishment year included irrigation, clipping of barley, weeding, and spraying for insects such as caterpillars. Because there was little rain in the first spring at lower elevations plants were irrigated as described on page 68.

Planting and seeding times. Planting times at lower elevations were from December to early February, after the soil had been wet down at least 1 foot by rainfall. This early planting allowed the roots to begin growth into the surrounding soil at the earliest opportunity. At higher elevations, plantings were made as soon as possible after snowmelt, usually in April or May.

Seeding at lower elevations was in the fall. When the soil was dry, shrubs were usually seeded at the same time as grasses and

legumes. At higher elevations, shrubs were seeded in the late fall and in spring after snowmelt.

METHODS OF MAINTENANCE

After the establishment year, shrubs were left to fare as best they could without maintenance. Mortality from herbaceous competition was so high at lower elevations that all grasses and weeds were removed from plantings at Penn Valley in the second spring.

RESULTS

1. CENTRAL COASTAL AND SIERRA NEVADA FOOTHILLS

SPECIES ADAPTATION

From 1971 to 1974, 60 shrub species from container-grown stock were planted in 21 locations at Crystal Springs and along State Highway 49. These were mostly drought-tolerant species, and little or no irrigation was used in establishing them. The shrub species, along with growth forms, possible uses, expected survival rates, and establishment ratings are listed in Appendix Table 19, page A-30. Common and botanical names begin on page D-1. The expected survival percentages are rates adjusted to the survival that might be expected if there were little or no herbaceous competition and little or no damage from mice and grasshoppers. These percentages could be expected only with careful planting procedures, favorable climate, near-zero competition from herbaceous species, and near-complete control of mice, grasshoppers, and other predators. A wildfire through herbaceous vegetation would be expected to cause almost 100% shrub mortality.

The locations of the plantings, the soil series, and the parent material are listed in Appendix Table 20, page A-35. Unfortunately, large cut and fill slopes have little true soils but are cut deep into or made out of parent soil material. The parent soil material is often rock in hilly or mountainous areas. Consequently, the growth of any species is often better related to parent materials than to soil series.

The shrubs were tested for three uses: 1) for revegetation, where only natives would be used to blend into the natural landscape, 2) as screens, which require rapid-growing evergeen shrubs, and 3) as bank plantings, which need prostrate or low-growing spreading shrubs less than 5 feet tall. Nine of the 60 shrub species planted show promise now, while several planted within the last 2 years are still too young to evaluate. The nine species of promise are separated into six with good survival and three with fair survival. Good survival would be 60-90% and fair survival would be 40-60%. Fair survival might be expected for most wild native shrubs, but that is speculation. The nine species are discussed below in approximate order of declining survival rates.

Good survival

1. Coyote brush. Coyote brush is a native of coastal and central Sierra Nevada foothills. The foliage is medium green. The plants, usually symmetrical when young, become "leggy" when mature, sometimes growing up to 12 feet. Coyote brush is used best in revegetation. It has a higher survival rate in the coastal foothills than in the Sierra Nevada.

2. Fourwing saltbush. Although fourwing saltbush grows mostly in arid or desert areas, it has survived remarkably well on fill slopes in upland areas. Survival was better in the Sierra foothills than in the

coastal. Fourwing saltbush is a gray-green species with spreading branches. On deep soils it grows to 9 feet high. It is used best in revegetation.

3. Rockrose. Rockrose is a Mediterranean species. It is an erect glandular pubescent shrub about 4 feet tall at maturity. The pink flowers are colorful. Because it propagates easily from seed, it could be considered for a direct-seeded bank cover.

Photo 28. Coyote brush is a weedy invader on disturbed sites in the coastal foothills and one of the easiest shrubs to establish.

Photo 29. Fourwing saltbush grew to 5 feet tall in 2 years on a favorable fill slope at Ione.

Photo 30. Rockrose in foreground grew well in 2 years in highly fractured rock on a cut slope at Plymouth.

4. California buckwheat. This is a low-spreading dense native shrub usually less than four feet tall. The species and subspecies are found more in coastal southern California and in the arid and desert parts of eastern California. The small flowers are white with a pink tinge, sometimes forming a dense canopy over the plant. This is an excellent plant for revegetation. It grew better on cut than on fill slopes, probably because there was less competition, and better in the coastal than the Sierra Nevada foothills. Since it grows easily from seed, it too can be considered for a direct-seeded bank cover.

Photo 31. California buckwheat planted in southern California by the Los Angeles County Fire Department, Forestry Division also grew well at Crystal Springs and in the Sierra Nevada foothills.

5. Whiteleaf manzanita. An attractive whitish-leaved native shrub usually less than 10 feet tall which grows best in the Sierra foothills, where it is a wide-spread native. It is symmetrical when young but tends to become "branchy" at maturity. This is an excellent shrub for revegetation but grows too slowly for a screen. It has been considered one of the most difficult plants to propagate.

6. Buckbrush ceanothus. This is the most wide-spread Ceanothus found in the foothills of California. It is variable in height but usually not over 10 feet tall. Although symmetrical when young, it tends to become "scraggly" when older. Buckbrush is best suited for revegetation.

Photo 32. Whiteleaf manzanita (left) and buckbrush ceanothus (right) on a cut slope at Plymouth.

Fair survival

7. Quailbush. Quailbush and its variety are found in alkaline areas from San Francisco and the San Joaquin Valley south and into the desert. It is a wide-spreading erect shrub usually less than 10 feet tall. Quailbush grows rapidly on better soils. It could be considered for a screen except that it tends to become somewhat ragged with age. It can be used best for revegetation.

8. Oleander. Oleander withstood severe barley competition at Crystal Springs Reservoir, south of San Francisco, but grew very slowly. It did not survive well in the Sierra Nevada foothills, where it slowly succumbed under stress from herbaceous competition, grasshopper attacks, and, possibly, cold weather. Oleander is a deep green, stemmy, flowering exotic shrub 5-15 feet tall. Without irrigation it may have little use. It is very poisonous but apparently very distasteful. Oleander, under irrigation, is used widely for landscaping and in median strips along California highways.

9. Wartleaf ceanothus. Wartleaf ceanothus and its variety are found throughout the coastal ranges of California. It is a deep green, loose branched shrub, usually less than 12 feet tall with small, narrow, deep green and glandular leaves. The flowers are deep blue and showy. The glandular leaves would catch dust if near traffic.

The height and spread of these shrubs at 3 years old and their height at maturity are listed below. These figures give some idea of their value for screens and bank plantings. Generally speaking , most

drought tolerant wild shrubs grow slowly without irrigation, making them marginal at best for screens, or for bank plantings unless they are short and grow readily from seed.

	Height and spread at 3 years (feet)	Height at maturity (feet)
1. Coyote brush	5 x 3	4-12
2. Fourwing saltbush	4 x 4	4-8
3. Rock rose	2 x 2	2-5
4. California buckwheat	1.5 x 2	2-4
5. Whiteleaf manzanita	2.5 x 1.5	5-12
6. Buckbrush	3 x 2	4-12
7. Quailbush	6 x 6	4-12
8. Oleander	1.5 x 1	5-15
9. Wartleaf manzanita	4 x 3	4-15

The maximum twig growth for three species during one year were 18 inches for coyote brush, 11 inches for buckbrush, and 10 inches for whiteleaf manzanita.

In addition to these shrubs, three others survived well in a single planting: Parry manzanita, a variety of big berry manzanita (puberula), and allscale saltbush. On a fill slope at Plymouth, allscale saltbush survived better in competition with annual grasses than any other species.

Several prostrate to low-growing species in the trials could be considered for ground covers. All are expected to require weeding maintenance, however. Without weeding, encroaching annual grasses, etc. will crowd them out. These include creeping sage, a prostrate species for use in fire control on southern California fuelbreaks by the USDA Forest Service, Pacific Southwest Forest and Range Experiment Station; 'Bandera' Rocky Mountain penstemon, a colorful low-growing species seeded and planted along highways in New Mexico; Osteospermum spinescens, a low-growing shrub; rosemary, a small leafed blue flowering plant long used in droughty landscaping (but reported to burn quite readily); and Caucasian sagebrush, a silvery-leaved prostrate species of questionable drought tolerance. Another promising shrub for ground cover and bank planting in the coastal area was prostrate coyote brush, particularly the 'Twin Peaks' variety. Neither an older strain nor the 'Twin Peaks' variety do well inland without irrigation, however.

Photo 33. Creeping sage in foreground that is one year old. In the second year creeping sage nearly covered the soil.

Photo 34. Creeping sage and squaw carpet ceanothus (together on right) cover the soil in a trial planting in southern California made by Pacific Southwest Forest and Range Experiment Station of the U.S. Forest Service.

Some recent additions have not been growing long enough to be evaluated. Those planted in 1973 and doing well are dwarf flannel bush, sulfur flower buckwheat, squawbush sumac, rock gooseberry, and Ceanothus roderickii. Those planted in 1974 were California sage, monkey flower, woolyleaf ceanothus, Lemmon ceanothus, sageleaf rock rose, Descanso rock rose hybrid, and 2 naturally occurring hybrids believed to be Ceanothus cuneatus x C. prostratus.

Four natives already used along highways (but with irrigation) did more poorly than expected. These were redbud, California coffeeberry, hollyleaf cherry, and toyon. The poor performance was due

Photo 35. A naturally occurring ceanothus hybrid believed to be Ceanothus cuneatus x C. prostratus. Hopefully, this shrub could be moved to lower elevations where low-growing shrubs are needed.

mainly to very unfavorable soil conditions. All should be tested further since they are very attractive shrubs.

Conclusions

The species differ in ability to establish on highways slopes without irrigation. The better species in these trials, in descending order of success were coyote brush, fourwing saltbush, rock rose, California buckwheat, whiteleaf manzanita, buckbrush, quailbush, oleander, and wartleaf ceanothus. All would be suitable for revegetation except rock rose and oleander, which are exotics. Quailbush was the only shrub that grew fast enough for screening, but is of questionable value because it may become "scraggly." As container grown stock planted at 10-foot intervals, none grew fast enough to

provide a bank cover. Other natives which appear promising for revegetation were a variety of bigberry manzanita, Parry manzanita, and allscale saltbush.

Promising prostrate or low-growing species for ground covers were creeping sage, 'Bandera' Rocky Mountain penstemon, and Osteospermum spinescens. Prostrate coyote bush did not appear vigorous enough to provide a ground cover without irrigation.

Recommendations

It is recommended that as many as possible of the better species be tested in any future plantings.

Implementation

These species will be considered where applicable in any future plantings.

ESTABLISHMENT OF CONTAINER-GROWN PLANTS

The procedures used in establishing container-grown plants were satisfactory. Survival was high in some plantings even without care after planting.

METHODS

The planting stock used in this study was usually 7 to 14 months old, depending on whether planting was at lower or higher elevations. In this age range the seedlings were usually woody at the base and less easily damaged by frost, transport, or by predators. Plants were also easier to start from seed in the spring than in winter or summer. Since rapid growing species such as saltbush could grow too large, they were kept small by starting several months later than most.

The planting holes were made 4 inches deeper than the plant container to allow space for the fertilizer well below the roots. No attempt was made to make holes much wider than the container, although with wider holes more soil would be loosened, which would facilitate root spread.

All shrubs were fertilized with 0.29 ounce of actual nitrogen per shrub plus phosphate and potash in slow-release form except for shrubs given another treatment in fertilizer trials. This amount increased the growth of several species but seemed to have little effect on others. Survival did not seem to be affected. These trials are described on page 69.

Trials

Irrigation trials. Several irrigation trials were conducted in the first year. Originally, the plants were not scheduled to be watered except at planting, and then only if the soil was dry or needed to be

firmed up in the planting holes. Since the first spring was droughty, however, many plants were irrigated to make up for the seasonal deficiency, which led to irrigation trials. The irrigation trials were conducted at four locations: Crystal Springs by the California Department of Transportation; Ione, Plymouth, and Missouri Flats by the Soil Conservation Service. The results were as follows:

Crystal Springs. Twenty-nine species and strains were included in the trials. Five of ten plants of each species were irrigated, and five were not. Five gallons of water were applied each month in May, June, and August in basins of 18-inch diameter. Survival was not increased by irrigation.

Ione. Five species were included in these trials. Six of ten plants of each species were irrigated, and four were not. Three, four, and seven gallons of water were applied each month in May, July, and September in 18-inch diameter basins. Survival was slightly in favor of the irrigated plants.

Plymouth. Two irrigation trials were conducted at Plymouth. One involved 29 species and varieties on a fill slope. Six of ten plants of each species were irrigated in May with 5 gallons of water, and four were not. The basins were 18 inches in diameter. Survival was 20% greater in the irrigated shrubs. There could be no response in five of the six species with the overall highest survival records, since their survival was 100% without irrigation. These species were fourwing saltbush, rock rose, buckwheat, buckbrush, and whiteleaf manzanita.

In a more lengthy irrigation trial on the same fill slope, buckbrush, rock rose, and fourwing saltbush were irrigated under three schedules: 1) five plants of each species were irrigated in May, each plant received 3 gallons of water, 2) five plants were irrigated in May and July with 3 and 4 gallons of water, and 3) five plants were irrigated in May, July, and September with 3, 4, and 7 gallons of water. Eighteen-inch basins were used.

Survival was 100% in all treatments for buckbrush and fourwing saltbush (as it turned out these species had high survival rates without irrigations). Rock rose, however, reacted favorably to irrigation. Survival was 70% from the May irrigation, 87% from the May and July irrigations, and 93% from the May, July, and September irrigations.

Missouri Flats. At Missouri Flats all plants of five species planted were irrigated in May with 3 gallons of water, and six of ten plants of each species were irrigated again in July with 3 gallons of water. There was no survival response to irrigation.

Fertilizer trials. Simple fertilizer trials were run at Crystal Springs and Penn Valley to get an idea how fertilizer affects shrub establishment. All fertilizer was mixed with the backfill material below the plant. The amount of nitrogen (N) used for each shrub was 0.29 ounce. Nitrogen was applied with and without phosphorus (P) and potassium (K). The fertilizer was applied in the winter when the shrubs were planted; observations were made the following summer.

Crystal Springs. In the summer of 1974, growth seemed doubled for coyote brush, allscale saltbush, quailbush, and California sage

with NPK slow-release fertilizer. There was no noticeable response for buckbrush ceanothus, coffeeberry, a variety of bigberry manzanita, whiteleaf manzanita, and dwarf flannel bush. Whether by happenstance or not, the first group of shrubs are naturally faster growing than the second. There was no difference in growth or survival between shrubs fertilized with NPK or with N alone, apparently nitrogen being the limiting factor.

Penn Valley. Slow-release fertilizer NPK quadrupled the growth of creeping sage in the summer of 1974. The fertilizer response was more pronounced in parent-material soil than in true soil. Again, there was no difference in response between NPK and nitrogen alone for creeping sage, California buckwheat, and fourwing saltbush.

Barley clipping trials. After the shrubs were planted at Crystal Springs, a dense stand of barley developed from volunteer seeds in the straw mulch, threatening shrub survival. In clipping trials to remove the competition, the barley was cut away from half of the shrubs in the middle of May.

Of the 29 species in these trials, 21 benefited from the clipping, and coyote brush and fourwing saltbush survived 100% in the clipped area. Where the barley was not clipped, all shrubs died except oleander, which survived 100% in spite of the competition. These results show the harm to seedling survival of severe barley competition and also show that seedlings will survive when competition is removed. Perhaps a cue to how much competition shrubs can survive was observed at Crystal Springs. On a rocky cut bank, shrub survival was good where the soil was only 25% covered by herbaceous vegetation.

Shrub mortality from grass competition was not confined to the first year; it was found in the second year as well. That was particularly apparent on the fill slope at Plymouth, where many shrubs competing with grasses died in the second year.

Competition

Competition from annual grasses and barley has been devastating to young shrub seedlings. The competition is believed to be more for moisture than for sunlight or soil nutrients. The 1972 plants of shrubs on a fill at Plymouth and the 1972 planting on a cut slope at Ione was almost entirely eliminated by annual grass competition. At both sites, annual grasses had been removed from around the shrubs by hoeing in winter, but by spring they had spread back.

At Crystal Springs, all the shrubs except oleander were eliminated by dense stands of volunteer barley plants which had developed from seed in the straw mulch. Oleander survived 100%.

At Shingle Springs, all shrubs died in competition with a dense stand of rose and Spanish clovers. This happened unexpectedly since all herbaceous species had been killed by Paraquat spray in December prior to planting. The clovers had developed from dormant seeds that germinated after spraying. A pre-emergence herbicide would have prevented this.

The shrubs that seemed to compete best against grasses and legumes were fourwing saltbush, allscale saltbush, coyote brush, and bladderpod.

Predators

Damage from predators such as field mice (Microtus sp.) and grasshoppers killed many shrub seedlings at lower elevations. Both predators (particularly the field mice) were associated with grass competition. Mice, for example, build up in dense stands of grasses and weeds but seldom venture into open ground more than a few feet away from cover. Grasshoppers, too, build up where there is food and do not seem to travel far into cleared areas unless under stress for food. At Plymouth, both predators moved up the slope into the shrubs from concentrations in dense herbaceous vegetation below. Neither field mice or grasshoppers traveled very far down cut slopes if the area between shrubs was open.

Field mice damaged plants by chewing bark off the main and lateral stems of shrubs, whereas grasshoppers concentrated on the leaves and tender stems. Neither predator seemed to damage saltbush species, though probably would if under stress for food. Field mice did little damage to coyote brush, though they sometimes chewed the base of plants. At Plymouth, grasshoppers defoliated coyote brush seedlings.

Photo 36. Buckbrush ceanothus stems girdled by field mice (Microtus sp.).

Photo 37. California buckwheat stems defoliated and girdled by grasshoppers.

Field mice were particularly damaging to the ceanothus and manzanita species.

Other predators causing damage were deer, gophers, and caterpillars. Deer in particular browsed blue blossom ceanothus and buckwheat at Crystal Springs before deer-proof fences were constructed. They did not seem to browse the saltbush species or coyote brush. Deer are known to seek out tasty, fertilized grasses, and the fertilized shrubs may have attracted them. Caterpillars defoliated blue blossom ceanothus at Plymouth. Gophers are believed to have caused damage to shrubs at Crystal Springs and Plymouth. No rabbits were noted in the vicinity of these trials but they are known to have caused severe damage.

Soils

Since most plantings were on deep cuts made through parent rock or on fill slopes composed of parent rock material, the parent material soil on the slopes did not greatly resemble the true soils. For this reason, it is questionable that shrub establishment can be related to true soils. Establishment might be best related to the fill or parent material. For example, if the parent material is deep or fractured so that the roots can penetrate it deeply, the seedlings survive well; if the parent material is droughty (shallow and impermeable) or gravelly, they do not.

On some cut slopes, shrubs grew poorly or died in true soil near the top of the slope. The poor growth in true soil was attributed to

the presence of a clay pan. At Crystal Springs, for example, all shrubs died at the top of the slope in the Montara clay-like loam series. Rainwater stood in the planting basins for several days, and the soil in the root zone was probably waterlogged throughout the winter, no doubt lowering shrub survival. No standing water was observed in planting basins in well-drained rocky parent material. On the other hand, shrubs in true soil at Penn Valley grew larger near the top of the cut in soil without clay pan.

Exposures

Exposures did not seem to influence establishment greatly although shrubs appeared to grow better on northerly exposures than on southerly. In several plantings, seedling losses were severe on both northerly and southerly exposures. In neither case was exposure blamed; the cause was grass or legume competition and damage by field mice and grasshoppers. At Penn Valley, however, cold and frost heaving was a problem on north-facing slopes where the soil had a high silt content.

ESTABLISHMENT OF SHRUBS BY DIRECT SEEDING

Direct seeding of shrubs by broadcasting seed on the soil surface or placing them in the soil, offers the possibility of establishing them with little effort; however, attempts to direct-seed them in central and northern California have not been especially promising. In comparison, in southern California CALTRANS has successfully broadcast seeded California buckwheat on many acres of highway slopes. Shrubs which germinate readily have given good results where there was little competition from herbaceous species in seedings made by the Los Angeles County Fire Department, Forestry Division. Among the shrubs were bladderpod, buckwheat, and various saltbushes.

A recent study, Chan et al. (4) indicated that hydromulch seeding was successful for a limited number of woody species when the soil was rough or loose, but that spot seeding was more effective. In spot seeding, the soil in selected areas or spots was loosened, fertilized, and seeded in a simple procedure. When necessary, grasses and other weeds in the immediate vicinity were controlled by herbicides.

Direct seeding was a small part of this study, but the findings are important since some important shrubs were tested and the results underline the harm of seeding shrxbs with competitive annual herbaceous species.

The 20 shrubs seeded at 12 locations and remarks regarding success and survival are listed in Appendix Table 21, page A-36. Seed of only about half of the species germinated. Those that germinated best were rockrose, California buckwheat, bladderpod, and balloon pea (though the balloon pea quickly died). Those that germinated fairly well were fourwing saltbush, black sage, wolfberry, and bitterbrush. Only a few seedlings developed for bigberry manzanita, buckbrush, blue blossom ceanothus, and quailbush. Quailbush might have germinated better if seeded in the winter instead of the fall.

Species that were expected to germinate but did not were white-leaf manzanita, Australian saltbush, toyon, and creeping sage. Australian saltbush and toyon are known to germinate easily from fresh seed, and the results with these species might have been better if the seed had been fresh.

The seeds were planted in three ways: 1) hand broadcast on a rough seedbed and then hydromulched with wood-fiber mulch and fertilized at regular rates, 2) seeded in small shallow contour furrows, lightly covered with soil, and then hydromulched and fertilized, and 3) spot seeded. Broadcasting seed on a rough soil surface did not give results much different from those for seeding in contour furrows. Spot seeding was not compared with seeding in contour furrows and on a rough seedbed.

Although emergence was often good for rockrose, buckwheat, etc., survival was poor. The high mortality was usually attributed to severe competition from annual grasses and legumes, although some seedlings also died even without this competition. Thus, shrub seedlings may be inherently weak or difficult to establish and less vigorous than grass seedlings. The shrubs with the best survival were California buckwheat, rock rose, and black sage. Bladderpod withstood competition from grasses better than the other shrubs.

Photo 38. At Sonora, many shrubs were started from broadcast seeding but few survived the competition, summer drought and damage from grasshoppers.

Although indications are that few shrubs survive in a heavy seeding of annual grasses and legumes, a number of shrubs have survived through the first summer at Watsonville in competition with barley on a protected north-facing slope. The survival there may have been due to the cool, moist summers. In a recent seeding of 'Luna' pubescent wheatgrass, rose clover, and poppy at Crystal Springs, a few California buckwheat seedlings remain alive. The reason may be the lesser competition from perennial grasses but this is not certain.

ESTABLISHMENT OF SHRUBS FROM SEED IN TOPSOIL

Another way of establishing shrubs is to use dormant seed found in topsoil from a shrubby area. This soil can be stockpiled during construction and spread over areas where shrubs are desired. Excellent results at Northstar at Tahoe led to trials at lower elevations at Sonora and Watsonville. At Sonora, the topsoil was collected from around shrubs in a woodland area, and although a few buckbrush seedlings and one oak were counted, they died because of competition with a fairly dense growth of herbaceous species brought in with the topsoil. Soil coverage by the herbaceous species in observations on April 3, 1974, was estimated at 40%, a level that must have increased before the end of the growing season. This herbaceous competition might have been expected because of the many herbaceous species found in a woodland area.

At Watsonville, a topsoil from a more dense shrubby area yielded few herbaceous plants and more shrub seedlings. South and north-facing slopes differed a little, however. On the south-facing slope, the shrubs germinated earlier and there were more species, including two species hard to germinate, chamise brush and manzanita. The warmer south slope probably allowed more seeds to germinate. Many of the seedlings were from easy-to-propagate species such as monkey flower and blue blossom ceanothus. Since coyote brush seed could easily have been blown in by the winter winds, not all of these seedlings (possibly none of them) started from seed brought in with the topsoil. A cursory count on July 8, 1974, listed the following shrubs in the 10 x 30 foot plots:

Species	Number on south-facing slope	Number on north-facing slope
Blackberry	6	1
Ceanothus, blue blossom	12	7
Chamise brush	1	0
Coffeeberry	2	2
Coyote brush	10	6
Iceplant	5	2
Manzanita	2	0
Monkey flower*	22	53
Pine, Monterey	1	0
Total	61	71

*Identification not positive on all.

Since erosion occurred on the topsoiled areas, this problem must be reckoned with, particularly on large areas.

Conclusions

Shrubs can be established on highway slopes by planting them from containers in winter, but the degree of success is still questionable for at least two reasons: 1) the elapsed time in the study is insufficient to determine mortality, and 2) the survival figures were not from controlled conditions. They were variable and difficult to assess because of mortality from grass and legume competition, mice, grasshoppers, and deer.

Nitrogen in slow-release fertilizer increases the size of some shrubs, but there was no indication that survival was increased. There was little indication that basin irrigation increases the growth or survival of shrubs, particularly species with high survival rates. These passive results from irrigation trials may have been due to one of two contradicting reasons: 1) drought-tolerant wild species, particularly chapparal, are not geared to respond to summer irrigation, and 2) irrigation schedules and amounts were not adequate.

Competition from grasses and legumes can be devastating to shrub plants for at least 2 years after planting. Unless such competition is controlled, shrub plantings are likely to fail. The shrubs that competed most strongly with grasses and legumes were fourwing saltbush, allscale saltbush, coyote brush, and bladderpod.

Most shrub species can also be damaged by mice, grasshoppers, deer, and caterpillars and other predators. To have successful plantings these must be controlled. Keeping herbaceous material away from shrubs will alleviate the danger from mice by destroying their cover, but it will not necessarily control grasshoppers since they can fly in. Saltbush species were damaged very little by predators, probably because they were less palatable. No rabbits were noted in the vicinity of these trials.

Clipping barley away from the growing seedlings in late spring helped the survival of most shrub species. Several species survived

100% after clipping. Where barley was not clipped away, all species died except oleander, which survived 100% in competition with barley.

Shrub growth and survival appeared better in parent material soil than in true soils for reasons not understood. If the parent material is deep or fractured so the roots can get deep into the crevices, the plants survive well. If the parent material is droughty (shallow, compacted, or gravelly), they do not.

Exposure did not seem to affect establishment greatly, although shrubs seemed to grow better on northerly than southerly slopes. Where cold and frost heaving is a problem, severe damage may occur on northerly slopes.

Topsoil obtained from shrubby areas may contain dormant shrub seed which germinates after being spread over disturbed areas. Topsoil from brushy areas resulted in more shrub seedlings than did topsoil from woodland areas. So many herbaceous seeds came in with soil from woodland areas that the resultant herbaceous competition crowded out the shrubs. At Watsonville, many seedlings developed of easy-to-germinate species such as blue blossom ceanothus and monkey flower, whereas few developed of hard-to-germinate species such as manzanita and chamise brush.

When making shrub seedings or spreading topsoil with shrub seeds in it, care should be taken that the area does not erode.

Recommendations

Any large scale dryland shrub plantings, seedings, or movements of topsoil with shrub seed in it should be protected against erosion in the first year and against herbaceous competition for at least 2 years. Predators must be controlled.

Implementation

CALTRANS is using these findings in designing revegetation and general landscaping projects.

2. TAHOE BASIN AND VICINITY

The Tahoe Basin was selected for testing herbaceous and shrubby species mainly because protective plant covers are needed on disturbed soils to counteract the consequent accelerated erosion and accompanying deposition of silt and plant nutrients into Lake Tahoe. The area is also the center of a shrub area. Some species native in the Basin range into southern California and northern California; some from the Great Basin area overlap here. Other species growing on the western slope of the Sierra Nevada range such as deerbrush ceanothus and mountain misery are not found in the Basin, however. The parent materials in the Basin are also representative of many found in other mountainous areas. These include granitic, andesitic, and glacial modified material. The Tahoe Basin is also a convenient area for the trials, being relatively near to the Lockeford Plant Materials Center.

Major emphasis was on the testing of grasses and legumes for erosion control in the Basin with a much more limited testing of shrubs. Shrub testing was limited mainly to avoid overlap with U,C. Davis, which was already conducting a study there on the establishment of native shrubs.

RESULTS

Forty-six species and strains of shrubs were tested in the Tahoe Basin and vicinity. These included 16 species native to the Basin and 30 that were not. Native shrubs would naturally be adapted to the area although their performance on cut and fill slopes was not known. Nineteen plantings of shrubs were made of container-grown stock as shown in Table 23, page A-39, five with seed and one with dormant seed of native shrubs in topsoil. The locations, soil series and soil parent materials where container grown stock was planted are listed in Appendix Table 22, page A-38. The growth forms, possible uses, and percent survival of the container-grown stock are listed in Appendix Table 23, page A-39.

ADAPTATION OF EXOTIC AND OTHER SHRUBS NOT NATIVE IN THE BASIN

Five shrubs not native in the Tahoe Basin and vicinity proved promising: 'Bandera' Rocky Mountain penstemon, Caucasian sagebrush, bearmat manzanita, dwarf arctic willow, and slender arctic willow. Two promising shrubs (of lesser importance because of their appearance) were prostrate summercypress and common lilac.

Prostrate or low-growing shrubs for bank plantings

'Bandera' Rocky Mountain penstemon. 'Bandera' was one of the shrubs with the highest survival rates. It was not tested on loose textured coarse granitic materials but did well on the finer textured old lake deposits of granitic glacial origin and on andesitic parent material soil, which also is finer textured than granitic soil. 'Bandera' is a slow spreading prostrate species with deep green foliage and showy blue flowers. The flower stems are about 18 inches long.

Caucasian sagebrush. Survival on old granitic glacial material was good as long as competition from weeds was held down. Like many other prostrate species, Caucasian sagebrush is easily overtopped by other species. It is a slow spreading prostrate species with rather bright gray foliage, very fine and soft appearing, and eye catching. The inflorescences, about 6 inches high, are gray and attractive when young but turn white and lose their pleasing appearance when old. The centers of older plants tend to die out.

Bearmat manzanita or kinnickinnick. One accession from seed obtained from a CALTRANS planting at Mount Shasta is doing well in finer textured granitic old lake deposits of glacial origin. Bearmat manzanita grows close to the soil and, although it is a manzanita it does not have the look of most manzanita species. The foliage is deep green and the flowers are small, light colored, and bell shaped.

Prostrate summercypress. Survival was better on old lake granitic glacial material than on andesitic. Although the early growth form was dense and green, the stems turned brown in the fall. Summercypress is of questionable value along highways because of its poor appearance when brown.

Photo 39. Seedlings of three promising exotic species being tested in the Tahoe Basin are (left to right) 'Bandera' Rocky Mountain penstemon, Caucasian sagebrush, and arctic willow.

Dwarf arctic willow. Survival has been good on glacial granitic and andesitic soil material. Dwarf arctic willow is stemmy with very slender purplish stems originating near the base of the plant. The leaves are green and deciduous and the flowers are in catkins. Mature height is uncertain in the Basin, though it appears to be medium-sized at the Lockeford PMC. Cuttings were not tested but should root when planted in moist areas.

Slender arctic willow. Survival was similar to that of the dwarf arctic willow above. Its appearance is similar except that the stems are thicker and longer and in general more robust. Cuttings should root in moist areas.

Common lilac. Lilac grew well in andesitic parent soil material. Lilac has pleasing flowers but does not closely resemble any native shrub. It is a tall growing deciduous shrub.

ADAPTATION OF NATIVE SHRUBS

Sulfur flower buckwheat and big sagebrush have survived remarkably well, particularly where soil conditions were dry. Other species with fair to good survival rates were mountain pride penstemon, squaw carpet ceanothus, rubber rabbitbrush, antelope bitterbrush, greenleaf manzanita, mountain whitethorn ceanothus, and redosier dogwood.

Prostrate or low-growing native shrubs for bank plantings

Sulfur flower. This species has a high survival rate where soil conditions are dry, particularly compared with other shrubs. Sulfur flower is a semi-erect, low-growing shrub with gray-green leaves and bright yellow flowers that hold their brilliant color for several weeks. Growth is slow, and it is questionable whether these plants can form a dense cover without irrigation.

Mountain pride. This species is a low-growing prostrate or creeping shrub found in nature in more rocky and gravelly places. It might form a fairly dense cover where soil moisture conditions are good. Survival has been best on the finer textured andesitic parent material, but in nature it also grows well on granitic material. Mountain pride is one of the most showy native shrubs; the flowers are rose-red, and the foliage deep green. Lateral growth is believed to be slow.

Squaw carpet. The dense foliage of this prostrate growing plant might form a continuous cover. Survival has been only fair, even on soils that are less coarse in texture. Growth is slow, but one plant may form a mat up to 10 feet across.

Photo 40. Three promising low-growing or prostrate native shrubs for higher elevations are (left to right) sulfur flower buckwheat, mountain pride penstemon, and squaw carpet ceanothus.

Short-growing semi-erect native shrubs about 5 feet tall or less

Big sagebrush. This species has one of the highest survival rates on all soils, including coarse textured granitic ones. The gray appearance of the plant softly blends into the landscape. The dull gray flowers "brown off" in the fall detracting from the appearance of the foliage. Big sagebrush and rubber rabbitbrush are of Great Basin origin but mingle with mountainous species in the Tahoe Basin and at higher elevations along the eastern side of the mountain crest. They are seldom found in coniferous forest on the western (more moist) side of the Sierra Nevada Mountains.

Rubber rabbitbrush. Survival has not been as good as that of big sagebrush on coarse textured granitic soils, but this species has survived well on the finer textured andesitic parent material soil. Rubber rabbitbrush has rather stemmy gray foliage and produces bright yellow flowers later in the growing season.

Mountain whitethorn or snowbush. This species establishes slowly but grows vigorously. It survived well on the finer textured parent material soil. Snowbush is a spreading gray-green-leaved shrub with whitish stems that end in sharp spines.

Photo 41. Promising short-growing, semi-erect native shrubs about 5 feet tall were (left to right) mature native plants of big sagebrush, rubber rabbitbrush, and mountain whitethorn.

Semi-erect to spreading shrubs 5 feet tall or more

Antelope bitterbrush. Survival of bitterbrush has been rather erratic but is best on finer textured soils. This is rather unfortunate because it is one of the easiest species to propagate from seed. Bitterbrush is a gray-green shrub with rather inconspicuous small rose-shaped flowers. Bitterbrush is a browse plant preferred by deer but unless large plantings are made, it is questionable whether deer will seek it out in summer and fall when they are in the Basin.

Greenleaf manzanita. Survival has been good from container-grown plants even on coarse textured soil parent material. Greenleaf manzanita is a semi-erect species, with green leaves and rather conspicuous light-colored, bell-shaped flowers. Growth is slow.

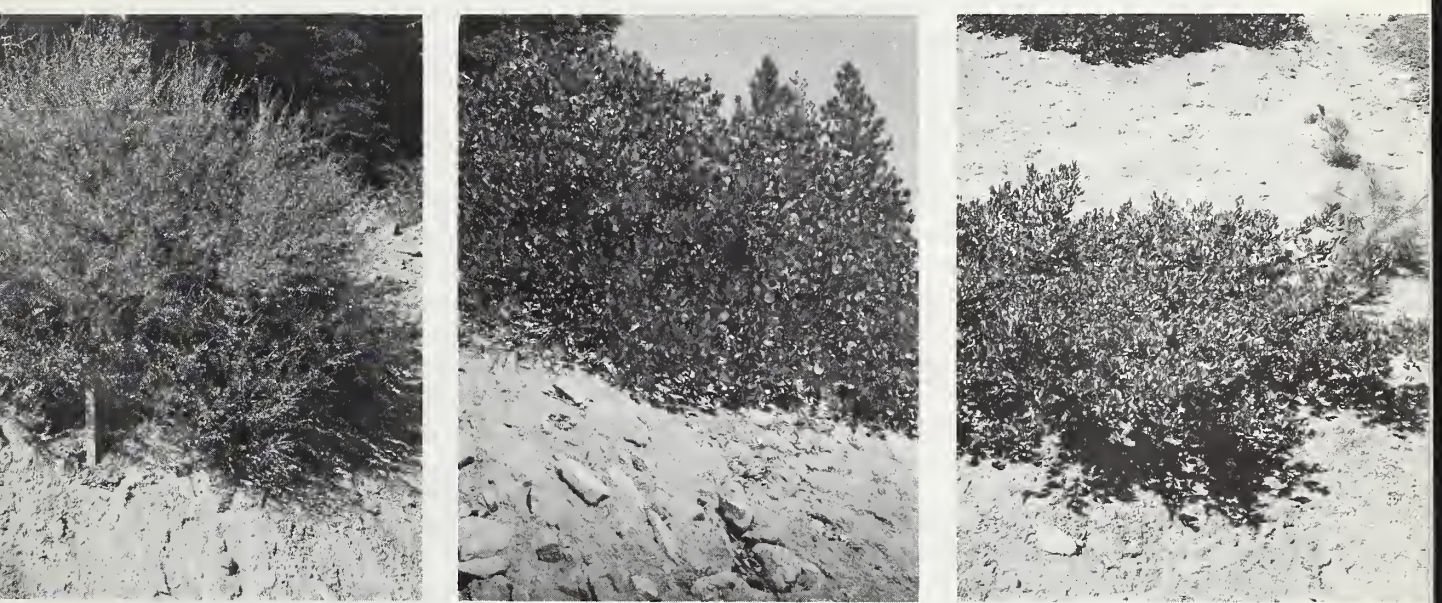

Photo 42. Three promising semi-erect native shrubs 5 feet tall or more for revegetating disturbed areas are (left to right) antelope bitterbrush, greenleaf manzanita, and tobacco brush ceanothus.

Redosier dogwood. Survival was good on andesitic parent material soil. Because seedling growth was robust, it was able to survive on an unstable slope while shorter seedlings were buried. It is a deciduous shrub with green leaves and colorful reddish twigs.

While these natives survived fairly well and were promising for revegetation or general landscaping, other shrubs were disappointing: pinemat manzanita, largely because it was difficult to propagate and few plants were field tested; Fresno mat ceanothus, because it did not survive well, although there was only one trial and competition

from weeds was rather heavy; and the saltbushes, probably because they grow best in arid areas where they are native. Some species were simply out of their range: rockrose, adelia, and Leucodendron nutans, all froze in the first winter. Promising native species that need work to improve establishment are tobacco brush ceanothus, pinemat manzanita, huckleberry oak, mountain whitethorn, squaw carpet ceanothus, and rubber rabbitbrush.

ESTABLISHMENT OF CONTAINER-GROWN STOCK

Container-grown stock was used in all establishment trials except those directly seeded or where shrub seed was brought in with topsoil obtained from around shrub plants. Bareroot plantings were made in the spring of 1975 and are too young to evaluate.

Methods

Healthy, vigorous planting stock was used whenever possible, although some plants were damaged when acclimatized to colder areas. Age varied but was usually 9-12 months, the stage when the plants are woody, and less susceptible to damage, and have a large root system. The plants were grown mostly at Pleasanton or Lockeford, in a Mediterranean climate, and transported to the Tahoe Basin several weeks before planting to permit acclimation or hardening off to the cold temperatures. They were hardened off by storing in an unheated building for at least 2 weeks before planting. In the spring of 1974, a number of plants were damaged by drought because they were held in the building for several weeks longer than expected and without irrigating.

Gallon cans were used in the first year, but thereafter most shrubs were propagated in 2-3/4 x 2-3/4 x 8-inch tarpaper bands. In the second year a container size trial was run at the airport with 8-inch plant bands, 1-3/4 x 1-3/4 x 6-inch tarpaper bands, and 2-3/4 x 2-3/4 x 12-inch bands. The shrub used in the trial was squaw carpet. There were eleven plants in each treatment. At the end of the first year, survival was 100% for plants grown in the 8-inch bands, 88% in the 6-inch bands, and 67% in the 12-inch bands. The results were in favor of the plants grown in the 8-inch bands. The problem with the 12-inch bands was that the soil column often broke apart, breaking the roots; otherwise, plant survival might have been 100%. Reasons for the lower survival in the 6-inch bands are only speculative, particularly since the trial was small and the difference may have been due to chance. Even so, the root mass was smaller in the smaller bands, and since the bands were shorter the roots were not placed as deep in the moist soil. With careful planting and watering, however, it seems reasonable that vigorous plants would survive equally well with root masses either 6 or 8 inches deep. At least two sides of all tarpaper bands were removed to insure that early lateral root movement would not be impaired.

Several new types of containers 6 to 8 inches deep and with a small soil capacity are now being tested at the Lockeford PMC. If

they prove practical and efficient, they should reduce the labor involved in handling and planting container-grown stock. These are discussed more fully in the section "Propagation of Woody Plants."

Irrigation trials. In 1972, simple irrigation trials were run at the Tahoe Airport to assess the effect that watering would have on shrub growth and survival in the establishment year. The shrubs were planted April 6, 1972, then watered at various intervals during the summer, 2 gallons per shrub each time. The basins around each shrub were 12 inches in diameter. Table 4 gives the species, irrigation schedule, and percent survival in the fall of the establishment year.

Table 4. Percent survival of shrubs in irrigation trials in the Tahoe Basin during 1972

Species	No irrigation	Irrigated July 1	Irrigated July 1, and August 1	Irrigated July 1, August 1, and Sept. 1
Nuttall saltbush	100	67	100	83
Caucasian sagebrush	67	50	67	83
Fresno mat ceanothus	17	67	33	33
Bearberry manzanita	17	33	33	50
Squaw carpet ceanothus	50	67	50	83
Average	50	57	57	66

Average survival rates are slightly in favor of irrigation, though the results are erratic and of questionable significance. It seems irrigation has little effect on survival, using these amounts and schedules.

Herbaceous competition. No trials were made of competition between perennial grasses and shrubs at higher elevations. All the same, almost all shrub seedlings planted into good 2-year-old stands of perennial grasses at the El Dorado County Airport were crowded out in the first or second year. A conspicuous exception was big sagebrush, which survived 100% although growth was retarded. One 'Bandera' Rocky Mountain penstemon survived, but it was only one-fifth the size of those without competition.

At two large housing developments it was noted that shrubs from seed in topsoil competed successfully with perennial grasses as long as the grass stands were not too dense and the shrubs apparently germinated at the same time as the grasses. This indicates shrubs survive in grass competition if started when the grasses are seeded and the subsequent grass competition is not too heavy.

Photo 43. Shrubs from seed in topsoil competing successfully in a grass stand that is not dense.

Exposure. Exposure affected plant establishment in that southerly slopes were warmer and drier than northerly slopes. At Northstar at Tahoe, survival differed little during a wet spring, but during a dry spring, shrub mortality on a south-facing slope was very high. Under these conditions irrigation would seem to be benefical. Three species that survived better than others in south-facing slopes were sulfur flower buckwheat, big sagebrush, and greenleaf manzanita.

ESTABLISHMENT OF SHRUBS FROM DIRECT SEEDING

Direct seeding of shrubs was generally disappointing, particularly since this method would be easy to use compared to planting container-grown shrubs. The first seedings were generally failures since only one species, bitterbrush, germinated, and only a few of those plants survived. Delayed germination was looked for in following years but none occurred. These trials were made by hand planting the seed into small contour furrows, although one was hydroseeded after mixing shrub seed into a slurry with grass seed, wood-fiber mulch, and fertilizer.

The species seeded in contour furrows included squaw carpet ceanothus, mountain whitethorn ceanothus, tobacco brush ceanothus, pinemat and greenleaf manzanitas, rubber rabbitbrush, big sagebrush, fourwing saltbush, and bitterbrush. Those hydroseeded were rubber rabbitbrush, big sagebrush, fourwing saltbush, and bitterbrush.

At Hope Valley, on a south-facing but cold slope, bitterbrush germinated in contour furrows during a warm period in March when the

snow was melted, but the tender seedlings were killed when cold weather returned. At the airport, many died from drought during summer on a more sheltered slope at the air terminal. No seedlings were found in the plot hydromulch seeded with grass and shrub seeds.

In the fall of 1973, seed of several shrubs were broadcast by hand in 10- x 30-foot plots and then covered with various mulches. The shrubs were bitterbrush, squaw carpet, greenleaf manzanita, and four-wing saltbush. Total seeding rate was 10 pounds per acre (2-1/2 pounds of each species). Both treated and untreated seed was used (greenleaf manzanita and squaw carpet ceanothus were both treated with concentrated sulfuric acid then stratified). The mulches were manure plus wood-fiber mulch (10 tons and 3,000 pounds per acre); manure and straw (10 and 2 tons per acre); wood-fiber mulch (3,000 pounds per acre); and a plot with no mulch at all. All plots were fertilized with ammonium phosphate sulfate 16-20-0 at 250 pounds per acre. The results, again, were poor: two bitterbrush seedlings were found in the manure-straw plot, and one in the manure-wood-fiber plot; no plants were found in the wood-fiber mulch plot. The seed treatments used did not help germination.

ESTABLISHMENT OF SHRUBS FROM SEED IN DUFF AND TOPSOIL

The best method of establishing shrubs from seed has been from native seed found in topsoil and in the partially decomposed layer of leaves and other organic matter on the soil surface known as duff. In this method, topsoil plus duff from a shrubby area is spread about one inch deep over the disturbed soil and the seeds are left to germinate. In these trials, bitterbrush was the only shrub seed that germinated, but it did not germinate well until the area was covered with bark chips at 10 tons per acre. The bark chips apparently shaded the soil, allowing moisture to remain near the surface long enough for bitterbrush seeds to germinate. Although soil and duff were also removed from under and around tobacco brush, greenleaf manzanita, big sagebrush, and rabbit-brush, no seedlings developed from these plants. This is puzzling since at two nearby development projects in which topsoil and duff were spread numerous seedlings developed of greenleaf manzanita, tobacco brush, mountain whitethorn, squaw carpet, and bitterbrush, along with some other shrub species. These treatments were repeated in the fall of 1974. By the following summer the results appeared similar except in addition to bitterbrush there were big sagebrush seedlings. Apparently, there were no viable seeds of the other species in the topsoil and duff. The absence of Ceanothus or Arctostaphylos seed may be attributed to rodents; the absence of rabbitbrush to poor seed. These results indicate that spreading topsoil and duff does not always guarantee seedlings of all species.

Photo 44. Shrubs established from native seed found in topsoil and duff.

Conclusions

Several exotic shrub species that appear promising for landscaping were 'Bandera' Rocky Mountain penstemon, Caucasian sage, bearmat manzanita, and two arctic willows.

Several native shrub species for revegetation or general landscaping were sulfur flower buckwheat, big sagebrush, greenleaf manzanita, mountain pride penstemon, rubber rabbitbrush, antelope bitterbrush, mountain whitethorn, squaw carpet, and redosier dogwood. Sulfur flower buckwheat, big sagebrush and greenleaf manzanita were the best species on coarse-textured, deeper granitic soils of glacial origin.

Generally, shrubs established better on finer textured parent material soil, such as old lake sediments of glacial-granitic origin or of andesitic parent material soil.

Exposure did not seem to be a problem in establishment as long as late spring rains kept the soil surface moist; otherwise, the soil surface on south-facing slopes dried rapidly, reducing shrub survival. Planting soon after the snowmelt seems a satisfactory time but requires that tender seedlings be acclimatized first or they may be damaged by freezing temperatures.

Method of planting, container size, and age of seedlings were satisfactory. Irrigation under the schedule used and the amounts of water applied did not improve establishment.

Direct seeding of shrubs has given poor results, whether hydro-

seeded with wood-fiber mulch; broadcast seeded and mulched with wood-fiber mulch or manure or manure and straw; or seeded by hand into small contour furrows. Bitterbrush was the only species in the trials whose seeds germinated.

Spreading topsoil containing shrub seed from shrubby areas on disturbed slopes has been successful only for bitterbrush and big sagebrush. Bitterbrush was most successful when the surface was mulched with wood chips (10 tons/acre). In two nearby development projects, results were much better when topsoil was simply spread on the soil surface. Found there, in addition to bitterbrush, were manzanita, tobacco brush, mountain whitethorn, squaw carpet, and other shrub seedlings.

Recommendations

The plantings and seedings should be monitored for several years to determine further survival.

Implementation

The species and methods of establishing shrubs are being considered by CALTRANS.

3. ALTURAS

Little work was done with shrubs at Alturas because demand for revegetation there is slight and precipitation is low, making container-grown stock difficult to establish. Several direct seedings of shrubs were made, with poor to encouraging results.

SPECIES ADAPTATION

Ten shrubs were seeded: bitterbrush, fourwing saltbush (a short strain from Bridger, Montana), big sagebrush, rubber rabbitbrush, greenleaf manzanita, squaw carpet ceanothus, silktassel, wolfberry, choke cherry, and common bladdersenna. Only bitterbrush and fourwing saltbush were successful, although on a fill slope the bitterbrush seedlings apparently froze. Fourwing saltbush seedlings were nibbled by jackrabbits. The reason big sagebrush and rubber rabbitbrush failed is not known, for they have volunteered in some areas from seed of native plants along the highway. One possibility for failure may have been that the seed was not viable; it has been found to be short-lived.

Photo 45. Bitterbrush seeded at Alturas.

Photo 46. Volunteer big sagebrush (left) and rubber rabbitbrush (right) on a cut slope at Alturas.

METHODS OF ESTABLISHMENT

Bitterbrush and fourwing saltbush became established from seeding in small contour furrows and from broadcasting seed on a rough soil surface. Both areas were hydromulched and fertilized after seeding. Later in the study, seeds were broadcast on the surface and then mulched with manure, manure and straw, and wood-fiber mulch. No seedlings resulted for there was little or no rain after seeding.

Conclusions

The better shrubs to use for revegetation would be big sagebrush, rubber rabbitbrush, and bitterbrush, all natives in the Alturas area. Big sagebrush and rubber rabbitbrush failed in direct seeding, however. Although bitterbrush was successful, there is considerable question about using it since it is a prime winter browse species of deer. Fourwing saltbush might be used, but its success has not been proven. It has persisted so far although damaged by jackrabbits.

Establishment of shrubs by direct seeding is difficult at Alturas. Only a few shrubs were successful probably because precipitation was often low in spring when needed, and seedlings were subject to damage by rabbits.

Recommendations

Do not seed or plant shrubs unless there is a special demand. Instead, let them invade naturally from plants in the vicinity.

Implementation

These results are being considered by CALTRANS in the design of erosion control plantings.

V. PROPAGATION OF WOODY PLANTS

by
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Shrub species that have potential for landscaping and revegetation of dryland sites on California highways must be easy to propagate for outplanting. This section describes methods used to propagate shrub species at the Lockeford Plant Materials greenhouse facility that are adaptable to a much larger scale of operations. Certain other methods that could prove valuable in larger scale operations are abstracted from publications.

Generally speaking, successful shrub propagation depends on three things: 1) developing reliable sources of plant material, 2) determining rooting and germination requirements, and 3) developing greenhouse cultural operations that produce ideal shrub outplants.

DEVELOPING RELIABLE SOURCES OF PLANT MATERIALS

Seed Collection

Most shrubs recommended in this report are not commercially available in volume and should be contracted for 1-3 years in advance of planting. Harvest from a reliable source of good seed is very important before a large scale propagation effort is initiated. Several methods can be used to harvest seed from wildland stands. The most elementary is hand-picking, the method used almost exclusively at the Plant Materials Center. Other methods include knocking seed onto canvas spread beneath the plant or into hand-carried hoppers. Vacuum collectors are frequently used to harvest seed from the shrub itself or off the ground. Seed that is dispersed by wind can be intercepted by fiberglass screens equipped with a canvas pocket that catches the seed as it drops from the screen. Plummer et al. described seed collecting methods for wildland shrubs in Utah.

Shrub species such as Atriplex are more productive and easier to harvest if grown on level cropland. Such species may even lend themselves to mechanical harvest as done for fourwing saltbush in a procedure developed by Stroh and Thornburg (14). The advantages to seed culture over wildland gathering are, if needed, greater production, collecting efficiency, seed integrity, disease and pest control, and mechanization. Drawbacks might include poor production because climates differ between the place of culture and the native habitat, and a tie-up of nursery space. With wildland collections, several factors determine where seed will be collected. Of utmost importance is the location of the ultimate revegetation sites. If revegetation is to be confined to a local area, seed should be collected from that local area if possible, or in areas with similar ecotypic conditions. If seed is collected for widespread planting, it should be from the most drought and cold-tolerant shrubs in its range.

Seed viability is very important. Before and during collection, small samples of seed should be cut open to determine the percentage of filled seed. Seed is considered to be filled when the endosperm and embryo are not damaged, shriveled, off-colored, or infested with insects. The endosperm and embryo should fill the seed cavity (unless they characteristically do not) and should be white in color. The minimum acceptable germination percentages as determined in germination tests in the greenhouse are given in Appendix Table 24, page A-43.

Time of collection may be very critical, often depending on minute ecotypic variances. For instance, during a hot spell Ceanothus drops all mature seed in a few days. Maturity dates vary with climate. Southern and low-elevation ecotypes generally mature fastest, and northern and high-elevation ecotypes slowest. Flowering periods, maturity periods, and methods of collection for several shrubs are shown in Appendix Table 25, page A-46.

Seed cleaning

Several methods of seed extraction and cleaning have been detailed by the U.S. Forest Service (15) and others (11, 12). The seed extraction and cleaning methods preferred for selected species and acceptable purity and germination percentages are listed in Appendix Table 24, page A-43.

Drying. Seed of some species is spread on screens, preferably indoors in a well-ventilated area, to be separated from their fruits by drying. Drying may be done at air temperature or in heated kilns.

Threshing. Pods or capsules need crushing to free the seed. This may be done on a small scale by beating or threshing. Agricultural hullers or shellers can possibly be adapted to thresh some species. Two machines that are used most widely in threshing are the macerater and hammermill developed by the U.S. Forest Service. The macerater containing a variable-speed drive, uses water to flush the seed through the machine. The hammermill, used for grinding feed materials, can be adapted for threshing shrub seed at low operation speeds, 400-800 rpm.

Depulping. Fleshy fruits must often be depulped to keep the seed from rotting. The most useful machine is the macerater. Other machines are the hammermill (if running water can be used to flush off the pulp), blenders, wine presses, concrete mixers, etc. Small lots can be depulped by hand by rubbing through screens. In most cases, running water is nearly always essential to separate the pulp from seed.

Dewinging. Species such as Atriplex can be dewinged with the hammermill or dewinging machines.

Screening. Several standard agricultural seed cleaning machines are available that separate seed from debris via a series of screens. Such machines often fan the seed in combination with screening.

Fanning. Forced air effectively separates seed from debris of differing weights.

Flotation. Fleshy fruits that have been depulped can be cleaned by flotation. Sound seeds usually sink, whereas poor seed, pulp, and

debris either float or sink slowly. This method can be used for dry fruits to obtain a seed lot with greater viability.

Seed storage

Most shrub species can be stored more than a year in a cool, dry area in mouseproof containers. Certain species, particularly Compositae (Chrysothamus and Artemisia), for example, are seldom viable for more than 1 year. The duration of good seed viability of selected shrub species is shown in Appendix Table 24, page A-43.

Collection of vegetative plant material

The guidelines for collecting cuttings in the wild are generally the same as for collecting seed. Proper sites and times of collection are essential for successful propagation.

Cuttings can be taken individually from plants, or larger plant parts can be judiciously pruned to provide cuttings. Care should be exercised not to upset the plants' aesthetic appearance by over-pruning. If space and time are available, shrub species can be grown near the propagation facility as a source of cuttings.

Once cuttings are taken in the field, they should be mixed with moist peat moss in loosely sealed plastic bags or damp clean burlap before they are transferred to the propagation facility. If storage is necessary, the bags of cuttings should be stored in a cool, shaded place. Cuttings should normally be placed in rooting media as soon as possible. At the Plant Materials Center, cuttings have been categorized into three types as described by Hartman and Kester (7): softwood, semihardwood, and hardwood. Softwood cuttings (3-5 inches) were taken in the spring from new vegetative growth. Semihardwood cuttings (3-6 inches) were taken from midsummer to fall from partially mature stems. Hardwood cuttings (4-30 inches) were taken in fall and winter from deciduous shrubs.

PROCEDURE FOR GERMINATING SEED AND ROOTING CUTTINGS

Seed pretreatment to break dormancy

There are two types of seed dormancy: seedcoat dormancy and embryo dormancy.

Breaking seedcoat dormancy. Seed with hard seedcoats were scarified mechanically or with acid or were soaked in hot water. Most effective of the three is acid scarification, but it must be closely monitored. Seed was soaked in concentrated (sp. gr. 1.84) sulfuric acid, at least one part to one part seed. It was stirred frequently and checked periodically to determine the degree of scarification. Adequate scarification took 5 minutes to 3 hours, depending on the species. Scarification was considered optimum when 7 of 10 seeds tested were soft (easy to cut open). In seed with irregular coats, however, scarification standards were different; the acid was

drained off when 1 or 2 of 10 seeds tested had exposed endosperms. Several commercial scarifiers are available for mechanical scarification, though the method is not used much at the Plant Materials Center. With some species, seedcoat dormancy was overcome by soaking in water heated to 170° F and then allowed to cool for 24 hours.

Breaking embryo dormancy. Two methods were used to break embryo dormancy in shrub seed; cold stratification and treatment with gibberellic acid. Cold stratification involved presoaking seed in water for 24-36 hours, placing the seed in loosely sealed polyethylene bags with an equal volume of moist peat moss or vermiculite, and subjecting it to 37-42° F for various periods.

Prolonged stratification may allow a seedlot to become moldy. A small amount of garden fungicide such as Captan, will alleviate the problem. Its effect on the germination of shrub seed appeared slight but was not determined. It has been reported to suppress the germination of conifer seeds (17).

Gibberellic acid (GA) was used to break dormancy in certain shrub seed, replacing cold stratification. Shrub seed was soaked for 24 hours in GA solutions ranging from 250 to 750 ppm and then dried for 24 hours before being planted. Seed thus treated with GA retained viability up to 3 years in storage at 37-42° F.

GA-treated seed germinated quickly and uniformly though the young seedlings were apt to be elongated by the hormone. The condition appeared temporary, however, with the seedlings outgrowing it.

Rooting cuttings

Cuttings were rooted at the Plant Materials Center by standard procedures described by Hartman and Kester (7). Cutting material was disinfected with Benlate and Captan (about 1 gram per gallon of water) before being placed in the rooting media. Cuttings were rooted under intermittent mist in perlite (No. 2 grand) with 75-80° F bottom heat. Cuttings in covered beds with no mist were rooted in 1:1 perlite and vermiculite (Horticultural No. 2) or 1:1 peat moss and perlite. Rooting was stimulated by commercial rooting hormones.

Photo 47. Creeping sage being transplanted to tarpaper bands from cuttings rooted in perlite under mist spray.

NURSERY CULTURE AND OPERATION

Seeding and transplanting

High viability seed (50% or better germination) was planted in individual plant containers, 3 to 5 seeds per container. Less viable seed was seeded in flats or pots for later transplanting of the seedlings to individual containers. Although not used, mechanical seeders are more efficient in large operations, particularly vacuum seeders (7, 9). Planting depth did not exceed twice the diameter of the seed. A thin layer of Canadian sphagnum peat moss was sprinkled over the seeded containers to help control evaporation from the soil surface. Granite grit, obtainable from feed stores, can be sprinkled on the seeded containers to aid radicle penetration into the soil (9).

Potting mixes and container systems

Several potting mixes were tried, depending on the container and species grown. Media used were soil, sand, Canadian sphagnum peat moss, perlite (No. 2 grade), and vermiculite (Horticultural No. 2). Two types of soil were used; Columbia fine sandy loam and Rescue sandy loam. Both were first sterilized with methylbromide. The container systems used were gallon cans, tarpaper bands, and Spencer-Lemaire book planters. Other systems available and probably adapted for highway slope plantings are the Japanese paper pot, Jiffy 7 peat

pots, Styroblock 8's, and RL single cells. Specifications for each are listed in Appendix Table 26, page A-49.

The most commonly used potting media in the nursery trade are media that are inexpensive and readily available, such as sand and soil, in addition to bark, sawdust, and peat moss. The major disadvantage of using sand and soil for large scale highway slope revegetation projects is that the containers become heavy. Subsequent work at the Plant Materials Center has concentrated on smaller containers and lighter (though more expensive) media. Appendix Table 27, page A-51, lists containers and media suggested for propagating shrubs and for planting out in the field.

Photo 48. Shrubs grown in gallon cans the first year at the Pleasanton PMC.

Photo 49. Shrubs in tarpaper bands in the lathhouse at the Lockeford PMC.

Sanitation

Standard practices were followed as outlined by Hartman and Kester and U.C. Manual 23 (1, 7).

Irrigation

A standard watering schedule was used for all shrubs at the Plant Materials Center. Since watering schedules depend on many factors they must be tailored to individual nursery operations through experimentation. As a general rule, waterings were thorough but as infrequent as possible. At the Plant Materials Center, plants were irrigated once a week in spring (March 15 through May 15), twice a week in summer (May 15 through September 15), and once a week in fall (September 15 through November 1). During 100° F weather the plants were watered three times a week. One inch of water was applied for every 5 inches of potting mix at each watering.

Many California chapparal and mountain shrub species require very well-drained soil media and infrequent waterings. When grown with riparian or other shrub types, separate watering schedules may be needed to avoid disease problems.

Fertilization

Fertilizer was standardized for all shrubs and applied in the irrigation water. A mixture of ammonium nitrate and diammonium phosphate (1:1 or 27-27-0) was applied at 5.0 ounces of dry soluble fertilizer per 100 gallons of water between May 15 and September 15. Between March 15 and May 15 or before, when the seedlings were 1 month old, diammonium phosphate (21-53-0) was applied alone at the same rate to encourage stem development. It was applied again between September 15 and October 15 to harden the shrubs for winter. Small monthly applications of potassium and micronutrients were added to the fertilization scheme. After fertilizer application, the shrubs were "washed off" to prevent accumulation of salts on the top growth.

Shade

Most shrubs were grown in a lathhouse or similar facility with 50% shade. Except for plants in gallon cans, the shrubs need to be shaded to stay healthy.

Root pruning

One of the main problems encountered in propagation was roots egressing from their containers: Flats of shrubs in tarpaper bands grew together; plants in gallon cans became anchored to the ground, etc. The Spencer-Lemaire book planter did not incur these problems. Roots did not migrate from one cell to another, and they were "air" pruned at the bottom. Styroblock 8's and RL single cells have the same features.

With gallon cans, placement on pallets can ensure "air" pruning. With tarpaper liners and similar containers, copper-naphthalate treated flats and plastic lining can prevent root egress, but their preparation is time consuming.

PROPAGATION RESULTS WITH SHRUBS TESTED FOR REVEGETATING HIGHWAY SLOPES

Forty-two shrub species, their propagation requirements, and anticipated success from results at the Plant Materials Center are listed in Appendix Table 28, page A-52. Species are categorized as easy or difficult to propagate and as not fully tested.

VI. PROPAGATION OF NATIVE SHRUBS FOR BARE-ROOT PLANTING AND SUCCESS IN ESTABLISHMENT

This study was designed to determine propagation and cultural procedures for increasing and transplanting bare-root stock of native plant materials that are difficult to grow, such as manzanita and ceanothus. If the material could be handled bare-root, the time and effort required would be much less than with container-grown stock.

METHODS

Bare-root stock was obtained from several sources: wildlings carefully collected from the field, container-grown stock with the soil removed from around the roots, and plants grown in beds from cuttings or seed. Wildlings and container-grown stock were used initially until stock could be grown in beds.

Planting bare-root stock in the field

Bare-root stock was planted in the same way as container-grown stock, i.e., in a hole 12-14 inches deep, made with a power auger. Fertilizer was mixed in with the backfill below the roots. Special care was taken to see that the roots were not exposed to air or sunshine and the soil was carefully firmed around the roots in planting. The plants from beds and container-grown stock were about 8 months old; the wildlings were 1 to 3 years old.

Rooting cuttings in beds for propagation of bare-root planting stock

Hardwood cuttings of seven native shrubs were placed in beds in the field in the winter of 1970-71 to see if they could be rooted. The cuttings averaged 3/8 x 8 inches and were made just before planting. The soil in the beds was cultivated about 8 inches deep and enclosed in wooden frames to keep out weeds. The beds were floodirrigated as necessary in summer. Three-fourths of the cutting was covered with soil. Three dates were used: February 11, March 15, and April 15. The shrubs used in this trial are listed in the "results."

Propagating shrubs from seed for planting bare-root

Thirteen high- and low-elevation shrub species were propagated from seed in beds at Lockeford for planting bare-root. One exception was coyote brush which was started in the greenhouse from seed sown in Jiffy 7 peat pots and then the seedlings plus containers were planted in the beds. The species are listed in the "results." In February 1974, beds were prepared by spreading 4 inches of ground redwood bark on the soil surface along with 600 pounds of ammonium phosphate sulfate 16-20-0 per acre and rototilling the mixture about 9 inches deep into the soil. The beds were then fumigated with methylbromide. Hard-to-propagate seed, such as ceanothus and manzanita,

were treated before being planted. The seed treatments were as described under "Woody Plant Propagation." For example, manzanita seed was treated with acid and stratified, while ceanothus seed was soaked in hot water and stratified, or treated with sulfuric acid and then gibberellic acid. The seeds were sown in furrows in April and May. after seeding the beds were mulched with wood-fiber making a layer about 1/8-inch thick. Partial shade was provided by lath fencing laid horizontally about 18" over the beds until the seedlings were well established.

Care was taken to give the seedlings adequate water in summer, whereas in the fall, the watering was reduced to allow the plants to go dormant and harden off before cold weather began. Irrigation was by a sprinkler system.

RESULTS

Planting shrubs bare-root at lower elevations has had encouraging results although the trials were not nearly as extensive as trials with container-grown material. Survival was almost as high for bare-root stock as for container-grown stock. The bare-root stock was planted in early winter at the same time as container-grown stock. One noticeable difference was that bare-root stock did not develop as rapidly in the first year.

Table 5 shows percent of survival of bare-root stock of several species in the first year. These percentages reflect the maximum

Table 5. Expected maximum survival of 10 native and 2 exotic shrubs in the north-central coastal and Sierra Nevada foothills using bare-root stock.

Species	Percent survival
Hard-to-propagate species	
Ceanothus, buckbrush	70
Manzanita, bigberry (var. puberula)	50
Manzanita, whiteleaf	50
Easy-to-propagate species	
Bitterbrush, antelope	40
Ceanothus, blue blossom	30
Coyote brush	80
Flannel bush, dwarf	70
Penstemon, 'Bandera' Rocky Mountain	40
Rock rose*	60
Saltbush, Australian*	60
Saltbush, fourwing	80
Wolfberry	40

*Not native.

survival expected for healthy plants planted carefully under favorable soil and climatic conditions, without real problems from weed competition, grasshoppers, mice, and other predators.

Although evidence is rather scant on the survival of bare-root stock beyond the first year, survival seems to be as good as with container-grown plants. Survival seems to depend largely on good soil conditions and absence of competition, particularly grass competition, just as with container-grown stock.

Photo 50. Bare-root plants of whiteleaf manzanita (left) and buck-brush ceanothus (right) survive 100% in the 1973-74 winter planting at Penn Valley. Elsewhere, survival was lower due to herbaceous competition, unfavorable climatic and soil conditions and to predators.

Propagation of bare-root stock from cuttings

Seven shrubs were propagated in the field from hardwood cuttings. Rooting was low compared with expectations in a greenhouse under mist spray. Even so, it did occur, particularly with stems of a variety of bigberry manzanita (rooting as high as 55%). Table 6 shows the results for three different planting dates. The percent rooted was determined in the next winter when they were dug for transplanting. There seemed little difference in success between the February and March dates except that the bigberry manzanita did very poorly at the later date. No rooting resulted with planting on April 15.

Table 6. Percent of cuttings that rooted in beds in the field when planted in February, March and April at the Pleasanton Plant Materials Center.

Species	Percent rooted from various planting dates 2/11/71	3/15/71	4/15/71
Grape, California wild	55	45	0
Bitterbrush, antelope	25	15	0
Adelia	20	25	0
Coyote brush	20	35	0
Saltbush, fourwing	20	23	0
Manzanita, bigberry (var. puberula)	55	7	0
Anderson wolfberry	(not planted)	80	0

Photo 51. Seven low elevation shrub species were rooted from hardwood cuttings in the field at Pleasanton PMC for planting bare-root stock along roadsides.

Propagation of seedlings for bare-root planting

Stock for planting bare-root was propagated in beds from seed of squaw carpet ceanothus, wartleaf ceanothus, buckbrush ceanothus, coyote brush, woolyleaf manzanita, whiteleaf manzanita, a variety of bigberry

manzanita, antelope bitterbrush, flannel bush, bladderpod, quailbush, fourwing saltbush, and Anderson wolfberry. These plants were healthy and strong. Similar success might be expected from properly treated seed of other native shrubs. Seeding was about 1/4-inch deep, which was satisfactory for these species with large seeds. Seeding depth might be a problem with small seeds. Some species were removed from the beds and planted at Penn Valley in the winter of 1974-75 and spring of 1975. Many of these survived the balance of a cold icy winter but it is too early to evaluate the results.

Photo 52. Thirteen low- and high-elevation shrub species were propagated from seed in beds at Lockeford PMC for planting bare-root along roadsides.

Conclusions

There is good evidence that stock of native shrubs for planting bare-root can be raised in beds from properly treated seed. Stock can be raised in beds from cuttings, though rooting is generally low. Survival on highway cut and fill slopes has been about as high for bare-root stock as for container-grown stock. Stock planted bareroot developed slowly in the first year, however. The planting procedure, similar to that used for container-grown stock, seemed satisfactory.

Recommendations

Small plantings of bare-root stock should be considered on a trial basis to determine the feasibility of making larger scale plan-

tings. These trials should be conducted under carefully controlled planting operations in areas where success seems likely. Any trials should be carefully designed, carried out, and monitored.

Implementation

Bare-root plantings made by CALTRANS have had varied success. The good results in this study encourage further trials using bare-root stock.

VII. SPECIAL STUDIES

1. SEEDING RATE TRIALS FOR EMERGENCY EROSION CONTROL

The quantity of seed to apply has puzzled designers of erosion control seedings for many years. It would be simple if seeding rates could be standardized and would produce uniform results. This has been done on range and pasture seeding, where the conditions are more uniform. Along highway cut and fill slopes, however, conditions are much more variable. The slopes vary from gently sloping to very steep, and the soils from extremely shallow to very deep. Soils and parent materials differ, and soil compaction is variable and stratified. Fertility also varies. There can be no definite time for seeding other than after construction is completed. Also, microclimatic conditions vary more around seed broadcast on the soil surface than in the soil. A few days variation in moist weather can affect germination greatly. This variance in conditions and subsequent results had led to seeding heavily for greater insurance. In reality, it would be desirable to evaluate the conditions of a slope, determine the erosion hazard and the amount of cover needed to protect the soil from erosion, and thus select the proper seeding rate. This study was conducted in a very simple manner, with the objective of determining some basic seeding rates which could be used or modified for the particular slope and expected weather conditions.

METHODS

Seeding rate trials were conducted with 'Blando' brome, 'Wimmera 62' ryegrass, foxtail fescue, and 'Arivat' and 'Briggs' barley. No subtle quantitative findings to link seeding rates to erosion rates were expected. The results were to be evaluated by seedling counts, estimates of soil covered by vegetation, and any discernible differences in erosion. The seeding rates (pounds per acre) were 20, 40, and 80 for 'Blando' brome and 'Wimmera 62' ryegrass; 10, 20, and 40 for foxtail fescue; and 45, 90, and 180 for the barley. The trials were conducted on rough seedbeds in areas of new construction. The seed was broadcast by hand and then hydromulched with 1,500 pounds per acre of wood-fiber mulch mixed with 500 pounds of ammonium phosphate sulfate fertilizer 16-20-0.

RESULTS

The numbers of seedlings were proportional to the amount of seed applied, though usually in less than a straight-line relationship. These are shown in Table 7. The deviation from a straight line may have been due to shortcomings in estimating numbers. It seems reasonable that the number of seedlings emerging should be directly proportional to the amount of seed, although weaker seedlings would later be crowded out by competition. In general, 'Blando' brome and barley seedlings were proportional to the amounts of seed applied, whereas 'Wim-

Table 7. Estimated percent soil covered by vegetation, number of seedlings per square foot, and height of several grasses and barley planted at various seeding rates early in the growing season in the north central coastal and Sierra Nevada foothills.

	Location and date of evaluation	Cut or fill	Percent soil covered			Seedlings per ft.^{2}			Height (inches)		
'Blando' brome			20*	40*	80*	20*	40*	80*	20*	40*	80*
	Crystal Springs	Cut	40	50	60	15	30	50	4	4	5
	12/20/72	Fill	30	80	80	15	25	40	4	4	4
	Grass Valley	Cut	3	5	15	30	40	100	1	1	1
	11/30/72	Fill	3	10	20	30	50	100	1	1	1
'Wimmera 62' ryegrass	Crystal Springs 2/08/72	Cut	25	27	26	40	49	125	3	3	3
Foxtail fescue	Sonora		10*	20*	40*	10*	20*	40*	10*	20*	40*
	1/11/74	Fill	6	8	14	80	100	150	1	1	1
'Arivat' barley	Crystal Springs		45*	90*	180*	45*	90*	180*	45*	90*	180*
	2/08/72	Cut	1	5	8	6	12	29	3	3	3
	Ione 2/03/72	Fill	2	6	8	5	12	29	3	3	3
	ALT 2/04/72	Fill	1	1	2.5	2	1	11	2	2	2
'Briggs' barley	Crystal Springs										
	12/20/72	Cut	40	50	60	8	12	30	12	12	12
	12/20/72	Fill	85	75	85	8	20	30	12	10	12

*Seeding rate in pounds per acre.

mera 62' ryegrass and foxtail fescue were less. For example, the numbers of seedlings of 'Blando' brome were estimated at 15, 30, and 50, almost a straight-line relationship for seeding at 20, 40, and 80 pounds per acre, and the numbers of 'Wimmera 62' ryegrass were 40, 49, and 125.

Seedling numbers of the same species varied considerably among sites. Numbers of 'Blando' brome, for example, were 15, 30, and 50 at Crystal Springs, and 30, 40, and 100 at Grass Valley (about double for the same seeding rates). In other seedings at 40 pounds per acre, variance among sites ranged from 30 per square foot to 170, nearly a six-fold range. The differences among sites are believed to be due to differences in seedbed and climatic conditions. For example, seed has a better chance of falling into depressions and germinating on a rough seedbed than on a smooth surface and with little contact with soil moisture. More seedlings can be expected after seeding when the rainfall is gentle and prolonged and the weather is warm; less if seeding is followed by abrupt storms and long periods of dry or cold weather.

The percent of soil covered was also proportional to seeding rates, though only early in the growing season. For example, at Grass Valley the coverage by 'Blando' brome on November 30, 1972, was 3, 5, and 15% for 20, 40, and 80 seeding rates. As the season progressed and individual plants stooled out and stems and leaves filled into vacant areas, differences in seeding rates became less pronounced or disappeared altogether. For example, with the rapid-growing 'Wimmera 62' ryegrass, differences in seeding rates were not discernible by February 8, when soil coverage was estimated at 25, 27, and 26% for seeding rates of 20, 40, and 80 pounds. Barley seedlings also stooled out into vacant areas and there was little difference in percent soil covered at the end of the growing season for the 45, 90, and 180 pounds per acre seeding rates, although the numbers of seedlings were closely proportional to the

Photo 53. Seeding rate trials with barley showed little difference in percent soil covered at the end of the growing season for the 45, 90, and 180 pounds per acre seeding rates.

amount of seed applied. If plants start to grow early while temperatures are still warm, they cover the surface much more rapidly than do seedlings that begin in cooler weather. Growth rates and soil coverage were more rapid on fill slopes than on cut slopes, undoubtedly because the supply of nutrients and moisture is greater in the deeper soils. Similarly, combinations of nitrogen and phosphate fertilizers increased growth rates and soil coverage. Actually, growth was very minimal unless fertilizer was applied on either cut or fill slopes. On toxic serpentine soils, growth was scant even with fertilization. Thus, the number of seedlings and percent of soil covered will vary at a fixed seeding rate; so a heavy rate, even knowing it is likely to be too heavy, is perhaps the best way of insuring a plant coverage. On the other hand, considering the factors that affect erosion, heavy seeding may be important only when the erosion hazard is high. For

Photo 54. On rocky slopes where the erosion hazard is low, a high seeding rate is not necessary.

example, the chance of much erosion is low on rocky slopes because rocks are not erosive, so that quick and full coverage is not a critical factor. Also, mulches (particularly straw mulches) provide protection from erosion early in the season so that it is not necessary to rely heavily on new vegetative covers for protection. Another factor to consider is time of seeding. When seedings are made early at lower elevations and effective rains come early, the cover developed by winter may be as good from a lower as from a higher seeding rate, whereas if the seeding is late, a higher rate would be desirable because growth would be slow. It should also be brought out that erosion did not differ discernibly between plots with different seeding rates. This was probably because the cut and fill material in most study areas was not highly erosive. There might have been differences, too, if the plots had been larger and more runoff water could have accumulated on the plots.

Conclusions

A number of variables affect the development of plant cover on a disturbed slope, just as a number of variables also dictate the desired density of cover. Until such variables can be determined, evaluated, and controlled, seeding rates can be determined only on a gross basis. In this study the seeding rate of 40 pounds per acre seemed generally satisfactory for grasses, except with the very small seeded ones such as

foxtail fescue where seeding rate was cut to 20 pounds per acre. Actually, these rates seem too high if conditions are favorable. Where there is an emergency situation, fast-developing annuals are seeded and these rates can be greatly increased, although the increased benefit of a high seeding rate is shortlived.

Recommendations

The recommended seeding rate for most grasses or combinations of grasses and legumes is 40 pounds per acre. This is a gross recommendation and subject to modification. Higher rates can be used where erosion is critical. The suggested seeding rate for barley is 180 pounds per acre, not only because the barley seed is much larger than grass seed but also because barley is usually used where erosion is critical and a quick cover is desired. It is also suggested that seeding rates be held constant for several years so it will be easier for personnel to monitor the seedings and to make any recommended future rate adjustments. This recommendation, however, does not preclude changing the set rate if the designer thinks it necessary. For example, the rate could be lowered on rocky surfaces or raised on erosive soils or for late seedings. Also, there may be unusual but expected losses of seed such as from birds or rodents eating the seed or from high winds blowing it away, and the rates need to be raised. But results are easier to evaluate if the seeding rate is held constant.

Implementation

The seeding rate of 40 pounds per acre for grasses and grass-legume combinations is being considered as a basic seeding rate around which lower or higher rates can be designed. Higher rates are used where rapid covers are needed.

2. RESPONSE OF NATIVE PLANTS ON HIGHWAY FIRESTRIPS TO HERBICIDAL SPRAYS

The effects of herbicidal sprays on native plants, particularly the California poppy, were closely observed on and in the vicinity of firestrips along highways in the Sierra Nevada foothills. The main objective was to determine whether damage resulted from winddrift or downslope movement of water.

METHODS

This study was made by observation from a moving vehicle and on foot in the vicinity of roadside test sites. About 500 miles of firestrip were observed. No chemical tests were made to detect herbicides in the soil or in plant tissue.

RESULTS

There is no evidence that the California poppy or any other cool-weather herbaceous species is resistant to herbicidal sprays applied on firestrips by the California Department of Transportation. A few exotic summer-growing grasses such as dallisgrass, bermudagrass, and johnsongrass survive, possibly because the foliar growth exposed at the time of spraying is not enough to absorb lethal doses; additionally, their roots in summer probably feed below the drier upper layer of soil where herbicides would concentrate. Turkey mullein, a native summer-growing fuzzy-leaved annual broadleaf species, also escapes the early sprays and survives. Another grass found in sprayed areas is annual bluegrass. It apparently sets seed before spraying, surviving in that way. Such species could be considered for vegetation

Photo 55. Herbicide sprays used by CALTRANS keep firestrips bare of California poppy and other herbaceous species, but the herbicides are often not lethal to young shrubs and trees.

of sprayed slopes--provided they don't become a fire hazard or are noxious weeds.

Herbicide sprays affect young shrubs and trees to various degrees. Some are damaged or killed whereas others seem unaffected. Live plants of whiteleaf manzanita, buckbrush, coyote brush, oak, and pine have been found in the spray strip. At a shrub seeding near Ione, quailbush and other seeded shrubs survived spraying during the second and third years after planting; they were not sprayed in the first year. This indicated that herbicides used by CALTRANS are not necessarily lethal to young shrubs and trees. It also indicates that select

Photo 56. Quailbush survived herbicide sprays applied in second and third years in the firestrips at Ione, indicating spraying is possible to control weed competition until the shrubs become well established.

herbicides can be oversprayed on shrub plantings to eliminate pernicious annual grass or weed competition.

There appeared to be no injurious drift of these herbicides with air currents. Sprayed strips on fill slopes were sometimes two to three times the desired width, but that appears due to poor spray control and to strong winds blowing the drops, rather than to drift. On cut slopes, the bare soil changes abruptly to resident herbaceous species, including California poppy, at the spray line. There appears to be no movement of lethal concentrations of herbicides downslope

Photo 57. There appeared to be no injurious drift or downslope movement of herbicides but the strips were sometimes two to three times the desired width.

by water, although, as mentioned above, the spray strips across fills are sometimes wider than expected.

Conclusions

Winter-active native herbaceous species were not immune to herbicide sprays used on firestrips along roadsides. Some summer-active perennial grasses and turkey mullein, a summer-active fuzzy-leaved native annual, escaped damage from the sprays. There was no apparent damage to native plants from spray drift in air, or from downslope movement by water.

Recommendations

It is recommended that all new sprays be evaluated on a small scale until their escape potential through air drift or movement by water is proven negligible.

Implementation

These results are being considered by CALTRANS.

3. USE OF FOLIAR ANTITRANSPIRANT SPRAYS IN ESTABLISHING DROUGHT-RESISTANT SHRUBS ALONG ROADSIDES

This study was originally outlined to test the effects of foliar antitranspirant sprays on maintaining unirrigated drought-tolerant shrubs along disturbed soils of highway rights-of-way. After careful thought, it was decided the sprays may have more immediate and perhaps greater application if used in establishing shrubs. If useful in establishment, the sprays would be further tested for maintaining these shrubs.

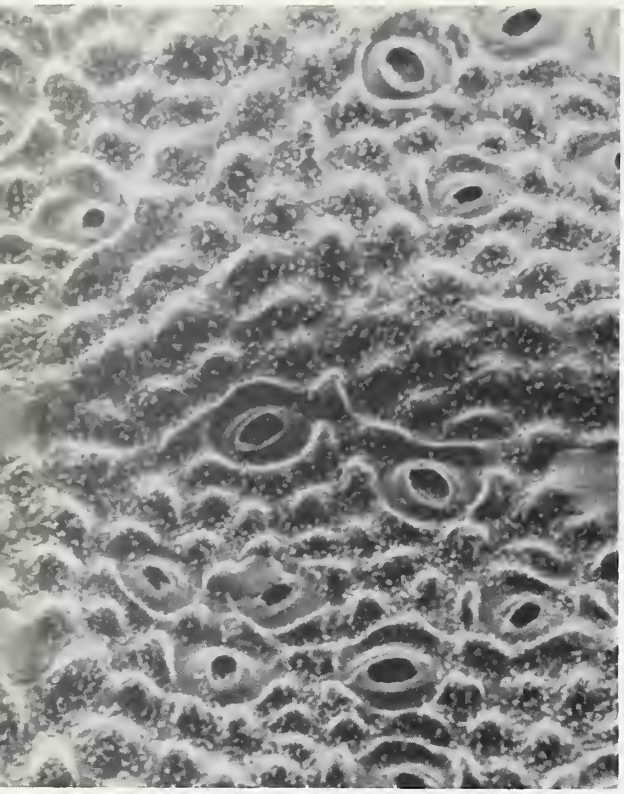
METHODS

After discussion with Dr. Robert Hagan and other members of the research staff of the Department of Water Science and Engineering (Dr. David Davenport, Paul Martin, and Mary Ann Fisher) of the University of California, Davis, a decision was made to conduct this study in three phases. Phases one and two were conducted by the Department. In phase one, the coverage of leaves of several drought-tolerant shrubs sprayed with an antitranspirant (AT) were assessed with the scanning electron microscope (SEM). Also, it would be possible to determine if there were any toxicity symptoms related to the AT spray. In phase two, some of the shrub species which appeared to respond to AT treatment in phase one were to be treated in the greenhouse for further use. In phase three, several of the more promising species were to be treated and tested in the field. The shrubs for use in phase three were planted on a cut slope at Penn Valley on January 18, 1974. They were sprayed on May 16 (about the time the native grasses appeared under stress for moisture in the soil) and again on June 14. The AT spray, 5% Mobileaf and 95% water, was applied with a hand-operated pressure sprayer.

Photo 58. Applying antitranspirant to shrubs at Penn Valley May 14, 1974 with a hand-operated pressure sprayer.

RESULTS

In phase one, SEM photos showed reason to believe that favorable results for AT sprays could be expected on whiteleaf manzanita, coyote brush, and rock rose. More detailed testing would be required, however, to determine whether fourwing saltbush, bitterbrush, and buckbrush would benefit from AT treatment. Squaw carpet would not be expected to benefit. During the first 10 days, symptoms appeared from the more concentrated solutions. Dilute solutions as previously used successfully in the field, however, were expected to yield the results desired in this study.



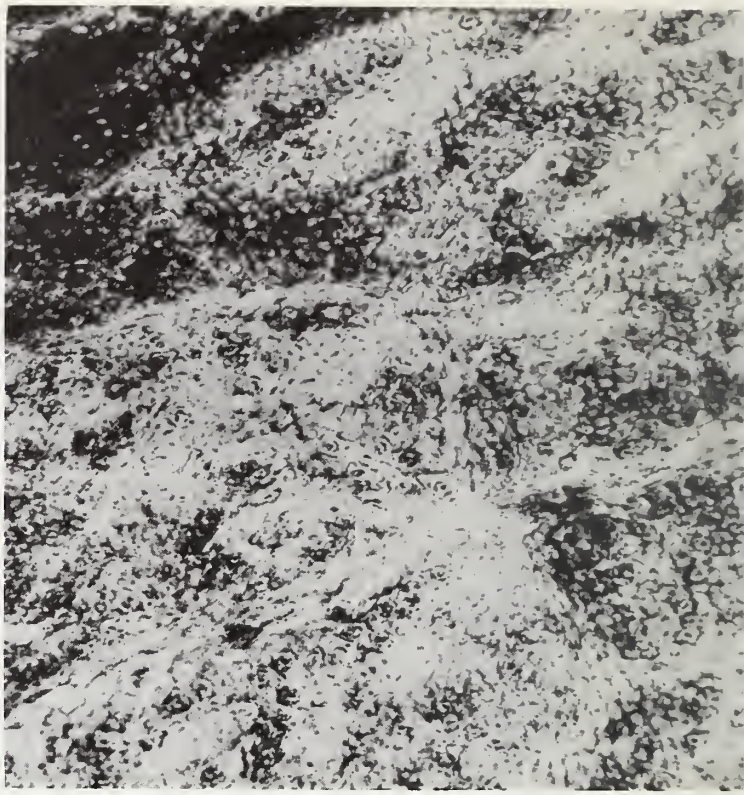


Photo 59. Photographs through the scanning electron microscope of a whiteleaf manzanita leaf shows unprotected stomata (leaf) and stomata covered by an antitranspirant film (right). Photographs from the Department of Water Science and Engineering, Univ. of Calif., Davis, Calif.

In phase two (in greenhouse) coyote brush, with its exposed stomata, responded well to treatment so that AT could be freely recommended for it. Fourwing saltbush, having a natural wax barrier on the leaf, responded to treatment much less dramatically, so that AT would be recommended for it only under conditions of stress or just as "insurance." Buckbrush experienced no substantial water savings, although the overall appearance was healthier.

In phase three, no effects on growth or survival from spraying AT were visible on coyote brush, fourwing saltbush, and buckbrush. A possible reason for the lack of response was that these species normally had high survival rates in the field. The dry condition of the soil may also have been a deterrent, since AT spray is known to be most effective when the soil is moist. There were only 5 plants of each species sprayed and 5 not sprayed so that there may not have been enough plants to determine a benefit.

Conclusions

Visually, there were no indications that foliar antitranspirant sprays aided in establishing coyote brush, fourwing saltbush, or buckbrush. These results are inconclusive, however, since those shrubs

are naturally drought-tolerant and have had high survival rates in plantings, and the soil was not moist at the time of spraying.

Recommendations

Before any large scale trials are attempted, the Department of Water Science and Engineering at U.C. Davis should be consulted.

Implementation

See recommendations above.

4. METHODS OF PROMOTING GROWTH AND PERPETUATION OF THE CALIFORNIA POPPY WITHIN THE HIGHWAY RIGHTS-OF-WAY

In recent years there have been reports of a decline of California poppy along highways. These are no doubt well founded since there have been many land use changes in which the native habitat of the poppy has been destroyed, such as a change to urban development or to irrigated farmlands. No quantitative data, however, show that poppies are declining naturally in undisturbed habitats. And, as with many other herbaceous species in nature, their numbers often vary from year to year, sometimes giving the impression of a decline. The objective of this study was to develop methods to promote the growth perpetuation of the California poppy along highway rights-of-way.

METHODS

Poppies were seeded in many annual grass-legume mixtures in several test areas and at Lockeford PMC to observe their establishment, growth, persistence, appearance, and compatibility with other species. Poppies were also seeded in several perennial grass-legume mixtures. Ammonium phosphate sulfate 16-20-0 fertilizer was applied in the first year at 500 pounds per acre. Some areas were fertilized again in the second and third years with 200 pounds per acre. Mowing and fertilizing trials were also begun at Lockeford in November 1973, to determine the effect of mowing on poppies in three annual grass-legume mixtures. The mixtures were 'Blando' brome or red brome or foxtail fescue seeded at 20 pounds per acre; rose clover, 10 pounds; crimson clover, 4 pounds; and California poppy, 6 pounds. Fertilizer, ammonium phosphate sulfate 16-20-0, was reduced to 400 pounds as the soil was fertile. The mowing dates were April 15 for some plots and July for others, and some plots were not mowed. The April 15 date corresponds closely to the time when soil moisture is reaching depletion in the Mediterranean-type climate. Mowing at that time would retard regrowth of the early-maturing annual grasses, thereby leaving more moisture for the later-maturing poppies during spring and summer. This date also corresponds to the date of mowing roadsides and interchanges. July would be an alternative mowing date. How well poppies survive and recover from mowing on these dates is not known. In the second year, one plot in each mowing treatment was fertilized with 200 pounds of ammonium phosphate sulfate fertilizer 16-20-0. Poppies were studied in their natural habitat to try to determine why they persist there.

RESULTS

In every instance where poppies were seeded with annual grasses and legumes, the number of poppies declined after the first year. In the first year, the number of poppy seedlings averaged two to six per square foot using a seeding rate of 4 pounds per acre for poppies. Many seedlings died in the first year because there were anywhere from 8-25 or more grasses per square foot to compete with. In the second

year, the numbers varied from an occasional poppy in a 10 x 30 foot plot to one per 2 square feet, and in the third year, from zero to one per square yard. In the second and third years, fertilizing with 200 pounds of ammonium phosphate sulfate fertilizer 16-20-0 reduced the poppy one-third below that in areas that were not fertilized. This reduction was probably due to increased competition from annual grasses, which noticeably responded to the fertilizer.

Poppies were seeded with several annual grasses including 'Blando' brome, red brome, foxtail fescue, and, last fall, big quakinggrass. Red brome was found to be the better grass in the first year because it did not compete as strongly as 'Blando' or foxtail fescue and it was lower growing, allowing the poppy flowers to show. Red brome, however, did not seem to persist long in the Sierra foothills, so its effect was short. It has already persisted 1-3 years at Crystal Springs.

Photo 60. Red brome was found the best grass to grow with poppies the first year because it did not compete as strongly as 'Blando' brome or foxtail fescue and was lower growing, allowing the poppy flowers to show.

Photo 61. 'Blando' brome, fertilized with 500 pounds of ammonium phosphate sulfate 16-20-0, grew tall the first year, hiding the poppy flowers. This may not occur if a lower fertilizer rate is used.

Poppies were recently seeded with perennial grasses, but there is no evidence yet that they persist any better with the perennials than with the annuals.

The native habitat of poppies is usually a rocky bank or loose gravelly or sandy soil into which the long carrot-like taproot can develop and where competition from grasses is less. Poppies apparently are not very competitive and require a loose soil in which the taproot can expand.

In comparison with grasses, the California poppy develops and grows almost as rapidly as 'Blando' brome, red brome, and foxtail fescue and thus can provide some erosion control. It does not have the fibrous root system common to grasses, however, so it cannot be considered as a substitute for them except on less erosive areas.

Mowing and fertilizing trials at Lockeford

Results from mowing and fertilizer trials at Lockeford may not be applicable to poppies on highway slopes because the soils at Lockeford are fertile and deep whereas soils on highway slopes are usually infertile and often shallow.

Table 8 shows the number of poppies in December at the end of the first growing season. Poppies, unlike the annual grasses did not die in late spring when the weather became hot but kept growing and flowering.

Originally, there were about two poppies per square foot in each plot, but by December many had died and volunteer seedlings appeared. There were more old plants in the mowed plots, however, the numbers varying from one-third to one per square foot in the mowed plots to one-fourth to one-ninth for plots not mowed. Apparently the mowing released the poppies from some grass competition, allowing more to survive. The poppy plants were badly mangled during mowing but they were able to overcome this damage and to grow and flower. 'Blando' brome and foxtail fescue appeared more competitive than red brome, for they had fewer poppies surviving among them.

Photo 62. The poppy plants were badly mangled in the April mowing (foreground) but were able to overcome this damage and to grow and flower.

Table 8. The average number of old poppies per square foot in six mowings and fertilizing treatments of 'Blando' brome, red brome, and foxtail fescue determined on December 4, 1974, at Lockeford Plant Materials Center.

	Number of poppies per square foot per treatment 1/					
	1F	2F	3F	4NF	5NF	6NF
'Blando' brome	1/8	1/3	1/3	1/4	1/3	1/3
Red brome	1/4	1		1/4	1	
Foxtail fescue	1/9	1		1/9	1	

1/ F = fertilized first year with 400 pounds 16-20-0, following year with 200 pounds.
NF = fertilized the first year with 400 pounds 16-20-0 but not in following years.
1&4 not mowed. 2&5 mowed in April. 3&6 mowed in July.

The second year, poppy numbers were far greater in plots mowed in April the previous year than in plots mowed in July or not mowed (Table 9). Most of these poppy plants were seedlings as many of the old plants had died. There was less duff in the plot mowed in April, which may have been the reason there were more poppy seedlings. There were more old poppies in the foxtail fescue plots than in the 'Blando' brome or red brome plots, possibly because the mature poppies were able to feed below the root zone of the early-maturing fescue.

Table 9. The number of poppies per 10 x 30 foot plot in six mowing and fertilizing treatments of 'Blando' brome, red brome, and foxtail fescue on April 28, 1975, at Lockeford Plant Materials Center.

	The number of poppies per 10 x 20 foot plot per treatment 1					
	1F	2F	3F	4NF	5NF	6NF
'Blando' brome	1	49	8	8	10	16
Red brome	6	33		5	30	
Foxtail fescue	50	85		50	150	

1/ See footnotes, Table 8.

Conclusions

Poppies persist poorly when seeded in combination with grasses on highway slopes. They may persist better if seeded alone, but in the end, they may persist only in their natural habitat--on rocky slopes or on gravelly or sandy soils where competition is minimal.

Ammonium phosphate sulfate fertilizer 16-20-0 applied at 200 pounds per acre in the second and third years increased the growth of grasses at the expense of poppies on highway slopes. There was no consistent difference on the fertile soils at Lockeford.

Poppies withstand mowing well. When mowing removes grass competition, the poppies recover and continue to grow and flower on deep fertile soils. Under these conditions, an April mowing gave more seedlings in the next year. This was attributed to a reduction in duff on the soil surface, a condition which may allow for better germination and establishment.

The first year, poppies grew better with red brome than with 'Blando' brome or foxtail fescue because red brome is less competitive. Red brome is also shorter than 'Blando' brome so the poppy flowers show above the grass. The reddish hue of red brome at maturity adds color to the mixture. In the second year, however, the most poppies were found with foxtail fescue, possbily because the mature poppies were able to feed below the root zone of the early-maturing fescue.

Recommendations

It is recommended that poppies be seeded under two conditions: 1) when their effects are wanted for only the first year, or 2) when they are being seeded in their natural habitat. It is further recommended they be seeded alone or with low-growing clovers or other flowers until a low-growing grass is available commercially. Possibly they could be seeded successfully with 'Blando' brome if the amount of fertilizer was reduced so that 'Blando' would not grow tall. Mowing in April is suggested to improve persistence and to let flowers show out of grasses. Heavy fertilizing is not recommended where annual grasses will benefit at the expense of poppies.

Implementation

CALTRANS personnel are using the above recommendations in designing erosion control seeding specifications.

VIII. SUPPLEMENTAL STUDIES

1. A COMPARISON OF CEREAL GRAINS FOR EROSION CONTROL

The California Department of Transportation has been seeding barley and other cereal grains for erosion control in the Mediterranean climate for many years. This seemed a practical procedure since cereals grow rapidly and the seed is cheap and readily available. There has been a question of which cereals or varieties are better. The following study was designed to compare selected cereals for erosion control. Suggestions were sought from the Agronomy Department, U.C. Davis; from Dr. C. A. Suneson (now retired from the U.S. Department of Agriculture); and from the plant materials and agronomy sections of the U.S.D.A. Soil Conservation Service.

METHODS

Thirteen species or varieties of cereal grains were included in trials at Pleasanton, Crystal Springs, and Ione, although not all were seeded at each location. Table 10 lists the eight varieties of barley, three of wheat, one of oats, and one of cereal rye. At Pleasanton the cereal grains were planted about 1-1/2 inches deep in rod rows, whereas at the other locations they were broadcast on the soil surface, hydromulched with wood-fiber mulch, and fertilized. Seeding rates were 90 pounds per acre broadcast, and 30 pounds in the rod rows. Ammonium phosphate sulfate 16-20-0 was applied at 500 pounds per acre and wood-fiber mulch at 1,500 pounds. Seedings were before the fall rains at Crystal Springs and Ione, and after at Pleasanton on December 21.

Table 10. Early relative ratings for erosion control, height at maturity, and early growth habit of several cereal grains at Pleasanton, Crystal Springs, and Ione during 1972.

Common name	Pleasanton accession number	Source	Early 1/ relative rating			Height at maturity (inches)			Early 2/ growth habit
			Pleasanton	Crystal Springs	Ione	Pleasanton	Crystal Springs	Ione	Pleasanton
Cereal rye	196-71	Commercial	2	NS	1	50	NS	48	SE
'Bluebird 2' wheat	184-71	U.C. Davis	2	2	3	20	20	18	E
'D6923' wheat	184-71	U.C. Davis	2	4	3	24	24	24	E
'Nugaines' wheat	191-71	Pullman PMC	3	4	3	24	22	23	SE
'Curt' oats	183-71	U.C. Davis	5	2	3	31	20	23	E
'Briggs' barley	180-71	U.C. Davis	1	1	2	30	24	23	SE
'CM 67' "	181-71	U.C. Davis	1	1	3	22	20	21	E
'Numar' "	182-71	U.C. Davis	1	1	2	26	22	22	E
'Luther' "	189-71	Aberdeen PMC	4	3	2	31	14	23	E
'Schuyler' "	190-71	Aberdeen PMC	4	NS	-	30	NS	-	E
'Blue mariot' "	204-71	CALTRANS	2	NS	2	22	NS	21	E
'Casbon' "	203-71	Corvallis PMC	3	NS	1	36	NS	23	SE
'Arivat' "	193-71	Commercial	2	2	2	38	NS	23	SE

NS = not seeded at this location.
1/ number 1 was rated highest, number 2 second highest, etc.
2/ SE = semi-erect, E = erect.

Photo 63. Thirteen species or varieties of cereal grains being evaluated at Crystal Springs.

RESULTS

In general, barley was better than wheat, oats, or cereal rye. The barleys obtained from U.C. Davis, including 'Briggs', 'CM 67', and 'Numar', provided the best soil coverage during early growth at Pleasanton and Crystal Springs. 'Casbon' barley and cereal rye were better at Ione. 'Briggs' barley was slightly favored over the others because of its somewhat sprawling growth habit which provided better soil coverage when the plants were young. 'Bluebird 2' was better than 'Nugaines' wheat. Cereal rye usually rated high for cover, and oats rated lowest. Height at maturity is an important consideration in fire control. The lowest growing cereal was 'Bluebird 2' wheat. It was only 18 inches

Photo 64. In row plantings at the Pleasanton PMC, 'Briggs' barley (sign) was slightly favored over the others because its somewhat sprawling growth habit when very young provided better soil coverage. Both 'Curt' oats (left of sign) and 'Nugaines' wheat (left of 'Curt' oats) were less vigorous than 'Briggs' barley when young.

tall at Ione. The lowest growing barleys were 'CM 67' and 'Blue Mariot', as short as 'Bluebird 2' wheat or only 2 to 3 inches taller. 'Briggs' and 'Numar' barley were a little taller than 'CM 67' and 'Blue Mariot', while 'Casbon' and 'Arivat' barley varieties were more than a foot taller than the shorter cereals. Some of the cereals had a semi-erect or a more sprawling growth habit when young, providing better soil coverage. These were cereal rye, 'Nugaines' wheat, and 'Briggs', 'Casbon', and 'Arivat' barley.

Photo 65. Cereal rye (left) grows tall and weedy at Ione while 'Bluebird 2' wheat (center) is about one-half as tall.

The longer a plant stays green the better it is for fire control. The cereals which stayed green longest were cereal rye, 'Nugaines' wheat, and 'Luther', 'Blue Mariot', and 'Casbon' barley. They stayed green 1 to 2 weeks longer than the earlier-maturing cereals: 'Bluebird 2' wheat, oats, and 'Briggs', 'CM 67', and 'Numar' barley. Each cereal performed similarly at different locations, although with noticeable differences. For example, 'Briggs' barley was the more vigorous barley early in the season at Pleasanton and Crystal Springs but not at Ione. Cereal rye matured earlier at Pleasanton than at Ione. These differences are not explainable since all sites were at lower elevations in the Mediterranean climate. They may be linked to differences in climate and soils. All the cereals matured and set seed. Few plants volunteered from seed.

Conclusions

Barley varieties were generally superior to wheat, oats, and cereal rye for early erosion control. 'Briggs' barley, an improved short barley obtained from U.C. Davis, was considered better than any other cereal tested because it not only started growth early but had a more sprawling early growth habit. Nearly as good were 'CM 67', 'Numar' and 'Blue Mariot' barley. 'Casbon' was better than 'Briggs' at Ione. Although cereal rye is an aggressive species, it is twice as tall as several short wheat and barley varieties. All cereals matured and set seed. Few plants volunteered.

Recommendations

Barley is recommended if a cereal is to be seeded at lower elevations. Suggested varieties would be 'Briggs', if available, or 'CM 67', 'Numar', or 'Blue Mariot'. Personnel acquainted with seeding barley on highway slopes may be consulted for recommendations.

Implementation

This information assures the erosion control designer that barley is better than other cereals for early erosion control and that the better varieties for early soil protection are 'Briggs', 'CM 67', 'Numar', and 'Blue Mariot'. While barley has been partially replaced by grasses in erosion control seedings, there could be a return to barley if grass seeds become increasingly scarce or expensive.

2. FIBERGLASS ROVING-ASPHALT EMULSION FOR EROSION CONTROL

This study was part of an "Environmental Improvement Research Project" conducted by the Transportation Laboratory of CALTRANS (implemented by CALTRANS Maintenance) in cooperation with the Federal Highway Administration. The objective was to test and demonstrate the use of fiberglass roving-asphalt emulsion covers for erosion control. The Plant Materials study was involved by providing seed and fertilizer for the treated areas and observing plant establishment and growth.

METHODS

In October, 1973, four waterways and about 1/4 acre of a gentle slope on the Ponderosa Road overpass on U.S. 50 were treated with fiberglass roving and asphalt emulsion. The areas were first shaped by a grader, seeded, and fertilized (by materials obtained from the Plant Materials Study), and then the fiberglass roving and asphalt emulsion were applied. A special nozzle was used to spread threads of fiberglass over the soil surface, forming a netting. Then asphalt emulsion was sprayed over the threads tacking them together. The application rates varied, fiberglass 0.40 - 0.55 lb./sq. yd. and asphalt emulsion (SS-1) 0.17 - 0.28 lb./sq. yd.

RESULTS

The fiberglass roving, under the weight and consistency of the asphalt emulsion, quickly conformed to soil irregularities, forming a protective erosion control mat. The asphalt emulsion also tacked the threads together. No erosion was observed in the treated areas; in

Photo 66. Waterway treated with fiberglass roving-asphalt emulsions at Ponderosa Road overpass.

Photo 67. Large stemmed species such as barley and 'Lana' vetch emerged through the webbing in the mat with little or no difficulty.

fact, sediment collected in the fiberglass netting. Even larger stemmed species such as barley and 'Lana' vetch emerged through the webbing with little or no difficulty except in small areas where overapplication of asphalt formed a continuous layer. Some seedling losses were observed. This was believed to be mainly the result of shallow droughty soils and possibly high soil surface temperatures from energy absorbed by the black surface.

Conclusions

The fiberglass roving-asphalt emulsion mulch easily conformed to soil irregularities, and plants emerged through the fiberglass webbing except in local areas where overapplication of the asphalt emulsion formed a continuous layer. Some plants died, possibly as a result of drought combined with high soil temperatures.

Recommendations

Trials should be extended to other areas, such as the desert.

Implementation

These results give assurance that grasses and legumes can emerge through the fiberglass roving.

3. AMMONIUM PHOSPHATE SULFATE FERTILIZER TRIALS WITH A GRASS-LEGUME MIXTURE

Cuts and fills on major highways are mainly in parent material below soil horizons at levels where nitrogen and organic material are scant. Rapid plant growth and development of a protective cover will require the addition of nitrogen. The common fertilizer rate has been 80 pounds of actual nitrogen per acre in combination with various amounts of phosphorus and sulfur. Potassium and iron have been included in the formulation sometimes.

METHOD

At Crystal Springs, ammonium phosphate sulfate 16-20-0 fertilizer was broadcast on both cut and fill slopes in 1972 at 0, 125, 250, 500, and 1000 pounds per acre. There were two replications on a cut slope, and two on a fill slope. Both slopes were new construction. The slopes were then seeded with a grass-legume mixture and hydromulched. Fertilizer responses were evaluated by estimating percent vegetative ground cover early in the growing season (December 31) and at the end of the growing season (June 21). The response to fertilizer was assumed to be mostly a response to nitrogen since that has been the usual case in fertilizer trials on rangeland.

RESULTS

Rains were early, with about 1 inch in late September wetting the soil about 5 inches deep. This was followed by overcast days, and the seeded grasses and legumes quickly germinated and began growing. In mid-October heavy rains assured enough moisture to keep the plants growing until winter rains. The grasses and legumes responded positively according to the amount of fertilizer applied (Table 11), though not in a straight-line relation.

Table 11. The percent of soil covered by a mixture of grasses and legumes on December 30, 1971, and July 21, 1972, after being fertilized with various rates of ammonium phosphate sulfate 16-20-0 fertilizer on September 11, 1971.

16-20-0 (pounds/acre)	Percent soil covered			
	Cut		Fill	
	12/30/71	7/31/72	12/30/71	7/31/72
0	9	8	12	78
125	15	23	27	88
250	30	25*	35	90
500	61	93	55	100
1000	75	95	65	98

*Leaves eaten by birds.

On December 30, estimated soil coverage was almost directly proportional to the amounts of 16-20-0 fertilizer applied up to 500 pounds, then tapering off to little increase beyond 1,000 pounds. Results were similar on the fill slope to those on the cut slope except that coverages were greater at the lower fertilizer rates and less at the higher. The cut slope was steep and erosive. The erosion was severe where no fertilizer was applied. Coverages were greater on July 21 than in December since the plants had several more months to grow. On the fill slope, the higher coverages in July at the lower fertilizer rates can be

Photo 68. Fertilizer trials on a steep erosive slope at Crystal Springs, no fertilizer (left) and 500 pounds of ammonium phosphate sulfate fertilizer 16-20-0 (right).

attributed to the plants getting more moisture and nutrients out of the deep fill soil than they did from the shallow cut soil.

Conclusions

Since the results are based on only a single year's data at two locations, they are more indicative than conclusive. Even so, ammonium phosphate sulfate 16-20-0 fertilizer was necessary to promote early plant growth. Without it, the cut slope eroded severely, defeating the basic objective. It also seems that early plant protection is proportional to the amount of fertilizer applied up to 500 pounds, above which the effectiveness decreased. Therefore, two ideas are suggested:

1) fertilizer amounts may be adjusted to the desired coverage (i.e., lower amounts on non-erosive slopes or on slopes where poppies are seeded and tall grass growth is undesirable), and 2) 500 pounds of fertilizer appears to be about the point where effectiveness declines rapidly, so a lower rate may be equally effective.

Recommendations

All slopes should be fertilized to establish plant covers rapidly for early erosion control. Since the cover's effectiveness varies with the amount of fertilizer applied, the erosion hazard must be considered; if high, apply 500 pounds per acre of ammonium phosphate sulfate 16-20-0 fertilizer; if lower, apply less. If poppies are seeded with the grasses and the erosion hazard permits lower fertilization, grass heights will be reduced perhaps letting the poppy flowers show better.

Implementation

This information is being used by CALTRANS in making fertilizer recommendations.

4. DRIP IRRIGATION

Drip irrigation is a method in which water is dripped at each plant. The principle of the drip system is frequent irrigation to keep the moisture level high in the root zone, eliminating stress between irrigations. In drip irrigation, water is distributed through tubing to an emitter located at each plant. The emitters drip at a set rate, allowing water to penetrate the soil directly at a rate that poses no danger of erosion. Once installed, the system requires little maintenance and minimal traversing of slopes. In the summer of 1971, a pilot study was carried out at the Pleasanton Plant Materials Center to explore the system for possible use in establishing shrubs, and also to get an idea of how drought-tolerant shrubs reacted to the system.

METHODS

In February, 1971, an area was prepared for trials at the Pleasanton Plant Materials Center. Plants of buckbrush ceanothus and whiteleaf manzanita were planted from gallon cans. In early summer a drip irrigation system was installed according to the distributor's recommendations. The shrubs were watered three times a week throughout the summer at three application rates: 1) 3 gallons per week from a 1-gallon-per-hour emitter, 2) 6 gallons from a 2-gallon-per-hour emmiter, and 3) no irrigation. The results by early fall are outlined next.

RESULTS

No difficulties were encountered by physically irrigating the plants. The emitters flushed and cleaned themselves of any salt deposits when the irrigation water was turned on and then dripped without problem. There was no runoff and the irrigations seemed adequate. Although of little consequence, the amounts of water released varied among the emitters from the designated quantity by 30%. The time spent in manually turning the system on and off could be mostly eliminated with an automatic timer.

The two shrub species in the trials responded somewhat differently. Buckbrush showed no visual response to irrigation. This might have been expected since the soils were deep enough to provide the slow-growing

Photo 69. Evaluation of the drip irrigation system at Pleasanton PMC.

drought-tolerant chapparal species with adequate water for growth without irrigation. For whiteleaf manzanita, however, the plants given 3 gallons per week appeared larger than those not irrigated, and the plants given 6 gallons seemed smaller. Thus, the lighter irrigation appeared to benefit whiteleaf manzanita, whereas the heavier one seemed slightly detrimental. The response was slight, however, so irrigation appears to be of little benefit in the deep soil. On the other hand, it did not seem harmful.

Conclusions

The drip irrigation system was not difficult to install or operate. The response of buckbrush and whiteleaf manzanita to such irrigation was little, if any, on the deep alluvial soils at the Plant Materials Center. The results could have been different on droughty soils.

Recommendations

Drip irrigation trials should achieve success on droughty soils before any extensive installations are made.

Implementation

CALTRANS is conducting drip irrigation trials.

5. THE EFFECT OF AMMONIUM PHOSPHATE SULFATE 16-20-0 FERTILIZER ON SEED AND LEGUME INOCULANT

Hydroseeding is often done by mixing seed, legume inoculant, fertilizer, and wood-fiber mulch into a slurry and spraying it on slopes. There has been some concern that ammonium phosphate fertilizer in solution would damage seed or legume inoculant if held in the tank of a hydroseeder for any length of time. A simple trial was done to determine damage.

METHODS

Ammonium phosphate sulfate 16-20-0 fertilizer was mixed with water in the proportion of 500 pounds of fertilizer to 3000 gallons of tapwater from the city of Pleasanton. The fertilizer shifted pH from 8.5 to 6.5 (near neutral). Added to the mixture in pint jars was seed of 'Blando' brome and 'Lana' vetch with inoculant. The mixtures were stirred occasionally, and seed was removed at set intervals for germination tests. 'Blando' brome seed was germinated in petri dishes and 'Lana' vetch in moist vermiculite. 'Blando' brome seed was removed at 1, 4, 24, and 72 hours and compared with seed not exposed to the mixture. 'Lana' vetch seed was removed at 1 and 4 hours and compared with inoculated and uninoculated seed not exposed to the mixture.

RESULTS

The germination of 'Blando' brome seed was not affected by exposure to the fertilizer in the mixture up to 24 hours but at 72 hours it was affected either by the fertilizer or from being in water too long. These results are shown in Table 12.

Table 12. The effect of ammonium phosphate sulfate 16-20-0 fertilizer in a slurry on germination of 'Blando' brome and 'Lana' vetch, and upon nodulation of 'Lana' vetch.

'Blando' brome*		'Lana' vetch*		
Hours in solution	Percent germination	Hours in solution	Percent germination	Percent with nodules
0	92	0 (not inoculated)	80	43
1	98	0 (inoculated)	84	95
4	98	1 (inoculated)	74	92
24	98	4 (inoculated)	60	90
72	46			

*50 seeds in each treatment.

The germination of 'Lana' vetch seed dropped off from 84% to 74% at 1 hour in the fertilizer slurry and to 60% at 4 hours, apparently affected in some way by the fertilizer. Nodulation, however, was affected only slightly. Interestingly, 'Lana' vetch nodulated without being inoculated, possibly from bacteria either on the seed or in the vermiculite. Had the pH of the solution shifted to below pH 6.5, lower nodulation percentages could have been expected. According to one report, the bacteria at pH 3.5 or lower would not be expected to live in appreciable numbers longer than 15 minutes.

Conclusions

Ammonium phosphate sulfate 16-20-0 fertilizer at the rate of 500 pounds per 3,000 gallons of water had no effect on germination of 'Blando' brome soaked for 24 hours in a water mixture at pH 6.5. This mixture only slightly reduced nodulation of 'Lana' vetch in 4 hours, but germination of 'Lana' vetch declined from 84% to 74% in 1 hour and to 60% in 4 hours. Thus it seems that grass and legume seed and legume bacteria may be little damaged by ammonium phosphate sulfate 16-20-0 within a few hours. At a lower pH, however, these results might change radically.

Recommendations

More trials should be run with ammonium phosphate sulfate 16-20-0 fertilizer and with ammonium sulfate (a substitute for ammonium phosphate sulfate fertilizer during the energy crisis). The variables should be the fertilizer and the pH.

Implementation

These results are being considered by CALTRANS for design specifications. Damage from fertilizer is entirely different from mechanical damage to seed.

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X. APPENDICES

Appendix A - Appendix Tables

Appendix B - Herbaceous Seeding Guide for California

Appendix C - A List of Native Shrubs and Trees for Revegetation and Erosion Control by Major Land Resource Areas

Appendix D - Some Common Names and the Varietal and Botanical Names of Species Mentioned

APPENDIX A

Appendix Tables 13-29

Table 13. Exposure, soil series, and soil parent material of 38 herbaceous seeding locations in the north central coastal and Sierra Nevada foothills from 1970 to 1974.

Location		Exposure	Soil series	Soil parent material
Crystal Springs	1970 Fill	N	Climara-like clay loam	Serpentine
	1970 Fill	S	Montara-like clay loam	Mostly basaltic, some serpentine
	1970 Cut	W	Climara-like clay loam	Serpentine
	1971 Cut	S	Gaviota-like sandy loam	Dominantly sandstone with basalt
	1971 Fill	S	"	and serpentine intrusions
	1972 Cut	E		
	1972 Fill	S	Montara-like clay loam	Mostly basaltic with some serpentine
	1973 Fill	W	Climara-clay loam	Serpentine
Placerville	1970 Cut	N	Diamond Springs very fine	Metadacite
	1970 Cut	S-W-E	sandy loam	"
Cameron Park	1970 F/C	S	Rescue sandy loam	Gabbrodiorite
	1970 F/C	N	"	"
	1971 Fill	S	"	"
	1971 Fill	N	"	"
Ione	1971 Cut	NE	Exchequer very rocky loam	Metasedimentary vertically folded rock
	1971 Cut	NE	Sedimentary rock sand	Sandstone and clayey marine sediments
	1971 Fill	SW	Exchequer very rocky loam	Metasedimentary vertically folded rock
Auburn Lake Trails	1971 Cut	NE	Boomer rocky loam	Metabasic
	1971 Cut	S	Boomer gravelly loam, near Auburn	"
	1971 Cut	SE	Boomer gravelly loam, near Mariposa	Metasedimentary

Table 13. Continued

Location		Exposure	Soil series	Soil parent material
Auburn Lake Trails	1971 Fill	SE	Mariposa & Boomer gravelly loam	Metasedimentary and metabasic
	1971 Fill	SE	Boomer gravelly loam	Metabasic
	1971 Fill	S	"	"
Grass Valley	1972 Cut	S	Aiken loam	Andesitic tuff, between acid and basic rock
	1972 Fill	S	"	
Sonora	1973 Cut	SW	Auburn loam	Metabasic schist
	1973 Fill	SW&N	"	"
Glenco	1973 Fill	E-S-W	Josephine silt loam	Mica schist
Watsonville	1973 Fill	S	Watsonville sandy loam	Sandy sediments
	1973 Fill	N	"	"
Danville	1973 Cut	SW	Altamont-San Benito clay complex	Soft shale and sandstone
	1973 Fill	N	"	"
Ponderosa Road Interchange	1973 Cut	W	Rescue very stony sandy loam	Gabbrodiorite
	1973 Cut	NW	"	"
	1973 Cut	SW	"	"
	1973 Cut	SE	"	"
	1973 Cut	S	"	"
Penn Valley	1974 Cut	W	Boomer loam over clay loam	Metabasic
	1974 Fill	SE	Loamy alluvial land	Mixed alluvium

Table 14. Evaluations of 53 herbaceous species and varieties seeded singly or in mixtures in the north-central coastal and Sierra Nevada foothills.

	Species	Stand establish-ment	Erosion rating 1st year	Erosion rating following years	Persistence	1/Appearance	Green period	Fuel volume	Tested singly or in mixture
1.	Alfalfa, 'Rambler'	Poor	Poor	Poor	Poor	Good	Into summer	Low	S
	Highly palatable to wildlife and not recommended for highways.								
*2.	Barley, 'Briggs'	Good+	Excellent	Poor	Poor	Fair, stemmy, shines when dry	Into spring	Medium	S,M
	The best barley for early erosion control in trials at Pleasanton PMC and at Crystal Springs.								
3.	Bentgrass, 'Highland' colonial	Poor	Poor	Poor	Poor	Good	Into summer	Low	M
4.	Bluegrass, annual	Good	Fair	Fair	Fair	Good	Matures early	Very low	S,M
	Evaluations based on recent trials in Penn Valley and on natural growth along freeways near Sacramento. Needs further testing.								
5.	Bluegrass, 'Sherman'	Erratic	Poor	Poor	Poor	Good	Into summer	Low	S
	Seeded only at Glenco in fall 1973 to test possibility of use in colder areas at lower elevations.								
6.	Brome, 'Cucamonga'	Good+	Excellent	Poor decreases	Poor	Fair stemmy	Matures early	Medium	S,M
	Discontinued trials because not generally superior to Wimmera 62 ryegrass or Blando brome. Commercial seed sources erratic.								
7.	Brome, field	Good	Good	Poor	Poor	Good	To summer	Low	S
	Trials indicate plants need late-spring rains to set seed. May be used for one year cover in drier areas.								

Table 14. Continued

	Species	Stand establish-ment	Erosion rating 1st year	Erosion rating following years	Persistence	1/Appearance	Green period	Fuel volume	Tested singly or in mixture
**8.	Brome, red	Good	Fair to good	Poor to good	Poor to good	Good until dries brown	Dries in spring	Medium	S,M
	Has reddish hue while maturing. Grows well with California poppy since not highly competitive and shorter, so poppy flowers are visible. Intended for use in areas of low rainfall. In large scale trials along highways.								
9.	Brome, seaside	Fair	Fair	Poor	Poor	Good	To summer	Low	S
	Does not appear to have outstanding characteristics.								
10.	Brome, 'Blando'	Good	Good	Poor to excellent	Good but variable	Good, blends well	Into spring	Medium	S,M
	In use on highway slopes. Has established on very compact soils where barley did not. Best all around annual grass for use in Mediterranean type climate.								
11.	Canarygrass, 'Cana' reed	Not known	Not known	Not known	Not known	Good	Late	Medium+	M
	Seeded at Penn Valley in fall of 1974 on wet areas only. Evaluations based on appearance at the Lockeford PMC.								
12.	Clover, crimson	Good	Fair	Poor	Poor to good	Excellent showy red flowers	Dries in spring	Low	M
	In use along highways in north coastal area where rainfall is higher.								
13.	Clover, rose	Good	Fair	Fair to good	Good on shallow soils	Good, colorful pink flowers	Into spring	Low	M
	In use in highway seedings.								

Table 14. Continued

	Species	Stand establishment	Erosion rating 1st year	Erosion rating following years	Persistence	1/Appearance	Green period	Fuel volume	Tested singly or in mixture
14.	Clover, Spanish	Fair at PMC	Poor	Poor	Erratic	Good, low growing	Midsummer	Low	M
	Seeded in fall 1974 in Penn Valley where trials are inconclusive. Evaluations based on performance at Lockeford PMC and on volunteer stands invading shallow soils on highway slopes.								
15.	Clover, 'Salina' strawberry	Poor	Poor	Poor	Poor	Good, low growing	Late spring	Low	S
	Performance may be better where the climate is more moist.								
16.	Clover, 'Mt. Barker' sub	Fair	Poor	Poor to fair	Erratic	Good, low growing	To late spring	Low	M
	May require mowing taller herbs in order to maintain subclover stands.								
**17.	Fescue, foxtail	Good+	Good to excellent	Usually good	Good on shallow soils	Fair to good, shines when dry	Early spring	Low to medium on cut slopes	S,M
	In large scale trials on highways. Naturally invades shallow soils on cut slopes. Cold-tolerant at lower elevations. Fine textured and carries fire rapidly.								
18.	Fescue, 'Durar' hard	Poor to fair	Poor to fair	Poor	Poor	Good, low growing	To summer	Low	M
19.	Fescue, 'Goar' tall	Poor to fair	Poor	Poor	Fair	Good	Into summer	Medium	M
20.	Finograss	Good	Fair	Fair to excellent.	Good	Good	Into summer	Medium	S
	Somewhat shorter and finer leaved than Hardinggrass but very similar, so testing discontinued.								

Table 14. Continued

	Species	Stand establish-ment	Erosion rating 1st year	Erosion rating following years	Persistence	1/Appearance	Green period	Fuel volume	Tested singly or in mixture
21.	'Hardinggrass'	Good	Fair	Fair to excellent	Good	Good	Into summer	Medium	S,M
	Should not be used where driver visibility could be obstructed. Can become bunchy.								
22.	Kolegrass, 'Perla'	Good	Good	Fair to excellent	Good.	Fair, tall stemmy	Into summer	Medium+	S,M
	Should not be used where might obscure visibility. Can become bunchy. Rodents chew bulb-like base of stem.								
23.	Lupine, Texas bluebonnet	Poor	Poor	Poor	Poor	Good, colorful	Late spring	Low	M
	Should not be seeded with competitive grasses.								
24.	Lupine, sky	Poor	Poor	Poor	Poor	Good, colorful	Spring	Low	M
	Should not be seeded with competitive grasses.								
25.	Milkvetch, 'Lutana' cicer	Poor	Poor	Improves	Good	Good	Late	Medium	M
	Seeded in wet area at Penn Valley. Evaluations are based on experience at Lake Tahoe.								
*26.	Oats, 'Curt'	Good	Good	Poor	Poor	Fair	Into spring	Medium	S
27.	Orchardgrass, 'Akaroa'	Poor	Poor	Poor	Poor	Good	Into summer	Medium	S
28.	Orchardgrass, 'Berber' Similar to Palestine? Seeded in fall 1974 in Penn Valley.								
29.	Orchardgrass, 'Latar'	Fair	Fair			Good			S
	Seeded at Glenco and not evaluated beyond first year.								

Table 14. Continued

	Species	Stand establishment	Erosion rating 1st year	Erosion rating following years	Persistence	1/Appearance	Green period	Fuel volume	Tested singly or in mixture
30.	Orchardgrass, 'Palestine'	Good	Good	Good	Good	Fair to good	Into summer	Low	S,M
	In large scale trials along highways. A strong competitor in mixture with other perennials.								
31.	Orchardgrass, 'Pomar'	Poor	Poor	Poor	Poor	Good	Into summer	Very low	S
32.	Pennisetum, feathertop	Poor	Seedlings froze at Crystal Springs during cold winter.						
33.	Pennisetum, fountaingrass	Poor	Seedlings froze at Crystal Springs during cold winter.						
34.	Poppy, California	Good	Fair	Poor	Poor	Excellent	Late summer	Low	M
	In use on highways. Has not persisted well in mixture with annual grasses. See Special Study 4.								
35.	Big quakinggrass	Fair	Fair	Not known	Not known	Good	Into spring	Low to medium	S,M
	Not fully evaluated. Seed heads attractive. Mixture seeded first time in fall 1974 at Penn Valley.								
*36.	Rye, cereal	Good+	Good+	Poor	Poor	Fair, tall stemmy	Into spring	Medium	S
37.	Ryegrass, annual	Good+	Good+	Usually decreases	Poor	Fair	Into spring	Medium	S
	Has been widely seeded on highway slopes, Straw often unsightly after maturing. Late maturing, so needs moist soil or coastal climate to set seed.								
38.	Ryegrass, perennial	Good	Good	Poor	Poor	Good	Into summer	Low to medium	S
	Not fully evaluated but appears to die out. May be useful where short-term cover is desired.								

Table 14. Continued

	Species	Stand establishment	Erosion rating 1st year	Erosion rating following years	Persistende	1/Appearance	Green period	Fuel volume	Tested singly or in mixture
39.	Ryegrass, 'Wimmera 62'	Good+	Excellent	Usually decreases	Fair on N Poor on S	Poor to fair	Into spring	Medium	S,M
	In use on highway slopes. May leave large amounts of unsightly residue.								
40.	Sweetclover, annual	Poor	Poor	Poor	Poor	Fair	To summer	Low to medium	S,M
	Erratic in establishment and persistence. Grows best in coastal or in wet areas.								
41.	Smilo	Fair & slow	Poor	Fair to good	Good on cut Poor on fill	Good	Into summer	Low	S
	Not good for initial erosion control since develops too slowly.								
42.	Trefoil, 'Cascade'	Seeded in fall 1974 on wet areas in Penn Valley. Not evaluated.							M
43.	Trefoil, narrowleaf	Poor	Poor	Improves	Fair	Excellent	To fall	Low	S,M
	Does best in wet areas and along roadside. Has colorful yellow flowers.								
44.	Vetch, 'Lana'	Good	Fair to good	May decrease	Erratic	Fair to good	Into late spring	Medium	S,M
	In large scale trials along highways. Difficult to mow. Persists better on deeper soils.								
*45.	Wheat, 'Bluebird 2'	Good	Good	Poor	Poor	Fair, short cereal	Into spring	Medium	S
46.	Wheatgrass 'Greenar' intermediate	Poor	Poor	Poor	Fair	Good	Into summer	Low	S,M
	Not adapted at lower elevations.								

Table 14. Continued

	Species	Stand establishment	Erosion rating 1st year	Erosion rating following years	Persistence	1/Appearance	Green period	Fuel volume	Tested singly or in mixture
47.	Wheatgrass, 'Tegmar'	Poor+	Fair	Fair	Fair	Good	Into summer	Low	S
	Not as well adapted at lower elevations as Luna.								
48.	Wheatgrass, 'Luna' pubescent	Fair	Fair	Good, improves	Good	Good	Into summer	Low+	S,M
	In large scale trials on highway slopes.								
49.	Wheatgrass, 'Topar' pubescent	Poor+	Inferior in establishment to Luna at Glenco.						
50.	Wheatgrass, 'Trigo'	Fair	Very similar to Luna, so trials discontinued.						
51.	Wheatgrass, 'Sodar' streambank	Poor	Poor	Poor	Fair	Good	Into summer	Low	S,M
52.	Wheatgrass, 'Barton' western	Poor	Poor	Poor	Poor	Good	Into summer	Low	S
53.	Wheatgrass, 727 western	Poor+	Poor	Poor	Poor	Good	Into summer	Low	S

1/ A good appearance would be one pleasing to see or blending with or harmoniously in color with the landscape. A poor appearance would blend poorly with the landscape or be otherwise unpleasant to see, such as stemmy, etc. Whether an appearance is good or poor could vary with the "eye of the beholder."

* Discussed more fully in cereal grain trials.

** Have sharp pointed seeds and awns and should not be used where dogs may be injured. Common in nature.

Table 15. Mixtures of grasses, legumes, and other herbaceous species seeded on cut and fill slopes from 1970 to 1974 in the north-central coastal and the Sierra Nevada foothills.

A. Annual mixtures

Mixture	% [1/]	Location	Year cut (c) and fill (f) [2/] 70	71	72	73	74
1 'Blando' brome	50	Crystal Springs	1c 2f	1c 1f	1c 1f		
'Lana' vetch	50	Cameron Park	2c 2f				
		Placerville	1c				
		Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
		Grass Valley			1c 1f		
		Watsonville				1c	
		Sonora				1c 1f	
		Glenco				1f	
2 'Cucamonga' brome	50	Crystal Springs	2c 2f	1c 1f			
'Lana' vetch	50	Cameron Park	2c 2f				
		Placerville	1c				
3 'Wimmera 62' ryegrass	50	Crystal Springs	1c 2f	1c 1f	1c 1f		
'Lana' vetch	50	Cameron Park	2c 2f				
		Placerville	1c				
		Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
		Grass Valley			1c 1f		
4 'Blando' brome	20	Crystal Springs	1c 2f	1c 1f	1c 1f		
'Wimmera 62' ryegrass	40	Cameron Park	2c 2f				
'Lana' vetch	40	Placerville	1c				
		Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
		Grass Valley			1c 1f		
5 'Blando' brome	50	Crystal Springs		1c 1f	1c 1f		
Annual sweet cl.	50	Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
		Grass Valley			1c 1f		
6 'Blando' brome	60	Penn Valley					1c 1f
'Wimmera 62' ryegrass	20						
'Lana' vetch	20						

Table 15. Continued

A. Annual mixtures								
Mixture	1/ %	Location	Year cut (c) and 2/ fill (f) 70	71	72	73	74
7 'Blando' brome	20	Crystal Springs	1c 2f	1c 1f			
'Cucamonga' "	20	Cameron Park	2c 2f				
'Wimmera 62' ryegrass	30	Placerville	1c				
'Lana' vetch	20	Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
8 'Blando' brome	50	Crystal Springs		1c 1f	1c 1f		
Rose clover	30	Auburn Lake Trails		1c 1f			
Cal. poppy	10	Ione		1c 1f			
Texas blue-bonnet 1971	10	Grass Valley			1c 1f		
Lupinus nanus 72							
9 'Blando' brome	60	Crystal Springs				1c 1f	
'Wimmera 62' ryegrass	20	Grass Valley				1c 1f	
Rose clover	10						
Cal. poppy	10						
10 'Blando' brome	40	Crystal Springs			1c 1f		
'Wimmera 62' ryegrass	10	Grass Valley			1c 1f		
Foxtail fescue	10	Sonora				1c 1f	
Red brome	10	Glenco				1f	
Rose clover	10						
Cal. poppy	10						
Lupinus nanus	10						
11 'Blando' brome	50	Sonora				1c 1f	
Rose clover	25	Glenco				1f	
Crimson clover	10						
Cal. poppy	10						
Narrowleaf trefoil	5						
12 'Blando' brome	33	Danville				1c	
Rose clover	33						
Crimson clover	17						
Cal. poppy	17						

Table 15. Continued

A. Annual mixtures

Mixture	1/ %	Location	Year cut (c) and fill (f) 2/ 70	71	72	73	74
13 'Blando' brome	50	Penn Valley					1c 1f
Rose clover	20						
Crimson clover	10						
Subclover	10						
Cal. poppy	10						
14 Foxtail fescue	50	Crystal Springs		1c 1f	1c 1f		
Rose clover	30	Auburn Lake Trails		1c 1f			
Cal. Poppy	10	Ione		1c 1f			
Texas bluebonnet 1971 only	10	Grass Valley			1c 1f		
Lupinus nanus 1972 only							
15 Foxtail fescue	50	Penn Valley					1c 1f
Rose clover	20						
Crimson clover	10						
Spanish clover	10						
Cal. poppy	10						
16 Foxtail fescue	50	Watsonville				2c	
Rose clover	25	Sonora				1c 1f	
Crimson clover	10	Glenco				1f	
Cal. poppy	10						
Narrowleaf trefoil	5						
17 Red brome	50	Sonora				1c 1f	
Rose clover	30	Glenco				1f	
Cal. poppy	10						
Lupinus nanus	10						
18 Red brome	50	Watsonville				2c	
Rose clover	25						
Crimson clover	5						
Cal. poppy	10						
Narrowleaf trefoil	2.5						
19 Red brome	50	Sonora				1c 1f	
Rose clover	25	Glenco				1f	
Crimson clover	10						
Cal. poppy	10						
Narrowleaf trefoil	5						

Table 15. Continued

A. Annual mixtures			Year cut (c) and fill (f) [2/]				
Mixture	% [1/]	Location	70	71	72	73	74
20 Red brome	50	Crystal Springs		1c 1f	1c 1f		
Rose clover	30	Auburn Lake Trails		1c 1f			
Cal. poppy	10	Grass Valley			1c 1f		
Texas blue-bonnet 1971	10						
Lupinus nanus 72							
21 Red brome	50	Penn Valley					1c 1f
Rose clover	20						
Crimson clover	10						
Spanish clover	10						
Cal. poppy	10						
22 Big quaking-grass	50	Penn Valley					1c 1f
Rose clover	20						
Crimson clover	10						
Subclover	10						
Cal. poppy	10						
23 Highway mixture							
'Blue Mariot' barley	52	Crystal Springs		1c 1f			
'Blando' brome	23						
Birdsfoot trefoil	21						
Cal. poppy*							
Texas bluebonnet*							
Coyote brush*							
*Accounted for in seed							
24 'Briggs' barley	80*	Crystal Springs			1c 1f		
*Lb/ac		Grass Valley			1c 1f		
25 'Briggs' barley	80*	Crystal Springs			1c 1f		
'Blando' brome	20*	Grass Valley			1c 1f		
Narrowleaf trefoil	10*						
*Lb/ac							
26 'Briggs' barley	80*	Crystal Springs			1c 1f		
'Blando' brome	20*			1c 1f			
'Lana' vetch	10*						
*Lb/ac							

Table 15. Continued

Mixture	% [1]	Location	Year cut (c) and fill (f) [2] 70	71	72	73	74
A. Annual mixtures							
27 'Briggs' barley	80*	Crystal Springs			1c 1f		
'Wimmera 62' ryegrass	20*	Grass Valley			1c 1f		
'Lana' vetch	10*						
*Lb/ac							
28 'Briggs' barley	80*	Crystal Springs			1c 1f		
'Blando' brome	12*	Grass Valley			1c 1f		
'Wimmera 62' ryegrass	4*						
Foxtail fescue	4*						
Red brome	4*						
Rose clover	4*						
'Lana' vetch	4*						
Cal. poppy	4*						
*Lb/ac							
29 Rose clover	30	Crystal Springs	1c 2f	1c 1f			
Crimson clover	30	Cameron Park	2c 2f				
Subclover	40	Placerville	1c				
		Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
B. Perennial and perennial-annual mixtures							
30 'Perla' kolea-grass	25	Crystal Springs			1c 1f		
'Luna' pub. wg.	50	Grass Valley			1c 1f		
'Palestine' orch. grass	25						
31 'Perla' kolea-grass	20	Crystal Springs			1c 1f		
'Luna' pub. wg.	40	Grass Valley			1c 1f		
'Palestine' orch. grass	20						
'Blando' brome	20						
32 'Perla' kolea-grass	20	Crystal Springs			1c 1f		
'Luna' pub. wg.	40	Grass Valley			1c 1f		
'Palestine' orch. grass	20						
Red brome	20						

Table 15. Continued

Mixture	% 1/	Location	Year cut (c) and fill (f) 2/ 70	71	72	73	74
B. Perennial and perennial-annual mixtures							
33 'Perla' kolea-grass	20	Crystal Springs			1c 1f		
'Luna' pub. wg.	40	Grass Valley			1c 1f		
'Palestine' orch. grass	20						
Foxtail fescue	20						
34 'Perla' kolea-grass	20	Crystal Springs			1c 1f		
'Luna' pub. wg.	40	Grass Valley			1c 1f		
'Palestine' orch. grass	20						
'Blando' brome	5						
Cal. poppy	10						
Narrowleaf trefoil	5						
35 'Hardinggrass'	80	Crystal Springs	1c 2f	1c 1f			
'Blando' brome	20	Cameron Park	2c 2f				
		Placerville	1c				
		Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
36 'Hardinggrass'	80	Crystal Springs	1c 2f	1c 1f			
'Wimmera 62' ryegrass	20	Cameron Park	2c 2f				
		Placerville	1c				
		Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
37 'Perla' kolea-grass	60	Crystal Springs	1c 2f	1c 1f			
'Wimmera 62' ryegrass	20	Cameron Park	2c 2f				
'Blando' brome	20	Placerville	1c				
		Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
38 'Perla' kolea-grass	80	Crystal Springs	1c 2f	1c 1f	1c 1f		
'Blando' brome	20	Cameron Park	2c 2f				
		Placerville	1c				
		Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
		Grass Valley			1c 1f		

Table 15. Continued

Mixture	% 1/	Location	Year cut (c) and fill (f) 2/ 70	71	72	73	74
B. Perennial and perennial-annual mixtures							
39 'Perla' kolea-grass	80	Crystal Springs	1c 2f	1c 1f	1c 1f		
'Wimmera 62' rg.	20	Cameron Park	2c 2f				
		Placerville	1c				
		Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
		Grass Valley			1c 1f		
40 Trigo int. wg.	40	Crystal Springs	1c 2f	1c 1f			
'Tegmar' int. wg.	30	Cameron Park	2c 2f				
'Sodar' stb. wg.	30	Placerville	1c				
		Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
41 'Luna' pub. wg.	40	Crystal Springs	1c 2f	1c 1f			
'Tegmar' int. wg.	30	Cameron Park	2c 2f				
'Sodar' stb. wg.	30	Placerville	1c				
		Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
42 'Luna' pub. wg.	40	Crystal Springs	1c 2f	1c 1f			
'Tegmar' int. wg.	20	Cameron Park	2c 2f				
'Sodar' stb. wg.	20	Placerville	1c				
'Blando' brome	20	Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
43 'Luna' pub. wg.	40	Crystal Springs	1c 2f	1c 1f			
'Tegmar' int. wg.	20	Cameron Park	2c 2f				
'Durar' hard fescue	20	Placerville	1c				
'Blando' brome	20	Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
44 'Luna' pub. wg.	40	Crystal Springs	1c 2f	1c 1f			
'Tegmar' int. wg.	20	Cameron Park	2c 2f				
'Durar' hard fescue	20	Placerville	1c				
'Wimmera 62' rg.	20	Auburn Lake Trails		1c 1f			
		Ione		1c 1f			

Table 15. Continued

Mixture	1/ %	Location	Year cut (c) and fill (f) 2/ 70	71	72	73	74
B. Perennial and perennial-annual mixtures							
45 'Luna' pub. wg.	40	Crystal Springs	1c 2f	1c 1f			
'Tegmar' int. wg.	20	Cameron Park	2c 2f				
'Sodar' stb. wg.	20	Placerville	1c				
'Wimmera 62' rg.	20	Auburn Lake Trails		1c 1f			
		Ione		1c 1f			
46 'Luna' pub. wg.	80	Watsonville				2c	
Rose clover	10	Sonora				1c	1f
Cal. poppy	5	Glenco					1f
Narrowleaf trefoil	5						
47* 'Luna' pub. wg.	80	Danville				1c	
Rose clover	10						
Cal. poppy	12.5						
Narrowleaf trefoil	2.5						
*Seeding rate for mixture, 60 lbs/ac							
48 'Luna' pub. wg.	80	Crystal Springs					1f
Rose clover	10						
Cal. poppy	5						
Narrowleaf trefoil plus	5						
Cal. buckwheat	2*						
Reseeded 1/29/74 'Palestine' orch. grass	4*						
'Blando' brome	2*						
*Lb/ac							
49 'Luna' pub. wg.	40	Watsonville			2c		
'Palestine' orch. grass	30	Sonora			1c	1f	
Rose clover	10	Glenco				1f	
Cal. poppy	10						

Table 15. Continued

Mixture	% [1]	Location	Year cut (c) and fill (f) [2] 70	71	72	73	74
B. Perennial and perennial-annual mixtures							
50 'Luna' pub. wg.	45	Penn Valley					1c 1f
'Palestine' orch. grass	20						
Annual bluegrass	10						
Rose clover	5						
Crimson clover	5						
Subclover	5						
Cal. poppy	10						
51 'Goar' tall fescue	40	Crystal Springs	1c 2f	1c 1f			
'Wimmera 62' rg.	20						
'Highland' bentgrass	20						
Narrowleaf trefoil	20						
52 'Goar' tall fescue	80	Crystal Springs	1c 2f	1c 1f			
Narrowleaf trefoil	20						
53 'Goar' tall fescue	60	Crystal Springs	1c 2f	1c 1f	1c 1f		
'Wimmera 62' rg.	20						
Narrowleaf trefoil	20						
54 'Cana' reed canarygrass	50	Penn Valley					1c
'Cascade' trefoil	25						
Cicer milkvetch	25						

1/ Seeding rate 40 pounds per acre except as indicated.
2/ 1c = seeded on one cut at the location indicated.
2f = seeded on two fills at the location indicated.

Table 16. Exposure, soil series, and soil parent material in 53 herbaceous seeding locations made in the Lake Tahoe Basin or vicinity from 1970 to 1974.

Location	Exposure		Soil series	Soil parent material
El Dorado Co. Airport South Tahoe				
1970 fall	Fill	E	Jabu sandy loam variant	Granitic alluvium
	Cut	E	" , with fine subsoil variant	Cut into fine compacted old lake sediment
	Cut	S	"	"
	Cut	E	Elmira gravelly coarse sandy loam	Granitic alluvium
1971 spring	Cut	E	Jabu sandy loam with fine subsoil variant	Cut into old lake sediment
	Cut	E	Jabu sandy loam with moderately fine subsoil variant	" (similar)
	Fill	E	Elmira coarse sandy loam	Granitic alluvium
	Fill	W	"	"
	Cut	E	Jabu sandy loam variant	Granitic alluvium, old lake sediment below
	Cut	E	Elmira coarse sandy loam	Granitic alluvium
	Cut	W	"	"
1971 fall	Cut	E	Jabu sandy loam variant	Cut into fine compacted old lake sediment
	Fill	E	"	Granitic alluvium
	Cut	S&E	"	Cut into fine compacted old lake sediment
	Cut	E	Elmira coarse sandy loam variant	Granitic alluvium
1972 spring	Cut	E	Jabu sandy loam variant	Cut into fine compacted old lake sediment
	Cut	E	"	"
	Cut	E	Elmira coarse sandy loam	Granitic alluvium

Table 16. Continued

Location		Exposure		Soil series	Soil parent material
El Dorado Co. Airport South Tahoe					
	1972 fall	Cut	E	Elmira coarse sandy loam	Granitic alluvium
		Cut	E	"	"
		Cut	E	"	"
	1973 spring	Cut	N&E	Jabu sandy loam variant	Granitic alluvium
		Cut	E	Elmira coarse gravelly sand loam	"
	1973 fall	Cut	S	Elmira gravelly loamy coarse loam	Granitic alluvium
	1974 spring	Cut	S	"	"
		Cut	E	"	"
Hope Valley on State 89					
	1971 fall	Cut	S	Meeks stony, loamy coarse sand	Glacial granitic
	1972 spring	Cut	S	"	"
	1973 spring	Cut	S	"	"
	1973 fall	Cut	S	"	"
	1974 spring	Cut	SE	"	"
Glenbrook to Spooner Summit					
	1970 fall	Fill	SE	Meiss cobbly loam	Andesitic
		Fill	W-NW	"	"
		Cut	E	Umpa very sandy loam	"
		Cut	NW	Cagwin-rock outcrop complex	Granitic

Table 16. Continued

Location		Exposure		Soil series	Soil parent material
Glenbrook to Spooner Summit					
	1971 spring	Cut	NW	Cagwin-rock outcrop complex	Granitic
		Fill	NW	Meiss cobbly loam	Andesitic
		Cut	E	Umpa very strong sandy loam	"
		Fill	SE	Meiss cobbly loam	"
Incline Village					
	1971 spring	Fill	NW	Inville stony coarse sandy loam	Granitic-andesitic alluvium
		Cut	S	"	"
		Fill	S	"	"
		Cut	E	"	"
	1974 spring	Cut	S	"	"
		Cut	S	"	"
Northstar at Tahoe					
	1973 spring	Cut	NW	Tahoma sandy loam	Jorge-Basalt, Tahoma-Andesitic or andesitic tuff
		Cut	SE	"	"
		Fill	NW	"	"
		Fill	SE	"	"
		Cut	NE	"	"
		Cut	S	"	"
	1974 spring	Cut	NW	"	"
		Fill	N-E	"	"

Table 17. Stand establishment ratings and reaction in mixtures and remarks regarding herbaceous species seeded in the Tahoe Basin or vicinity and Alturas.

Species	1/ T	A	Stand establishment Tahoe	Alturas	Reaction in mixtures and remarks
Alfalfa, 'Ranger'		S	NS	Poor	Not tested in mixtures.
Alfalfa, 'Rambler'	SM	SM	Poor to fair	Poor	Usually a small component in mixtures. In three years plants are large.
Barley, 'Campana'		S	NS	Poor	Not tested in mixtures.
Barley, 'Luther'		S	NS	Poor	Not tested in mixtures.
Barley, 'Schuyler'	S	S	Poor	Poor	Not tested in mixtures.
Beachgrass, American	S		Clones	NP	Not planted in mixtures. Good survival first year.
Bentgrass, 'Highland' colonial	S	S	Poor	Poor	Not tested in mixtures.
Bentgrass, red top	S	S	Poor	Poor	Not tested in mixtures.
Bluegrass, 'Sherman' big	SM	SM	Poor to good	Fair to good	Competes with other grasses. Increases coverage. Add blue color. Erratic.
Bluegrass, Kentucky		Seed collected at South Tahoe airport and seed increase started at Lockeford PMC in fall 1974.			
Brome, red	S	S	Poor	Poor	Not tested in mixtures. Seedlings died from drought at Alturas.
Brome, 'Manchar' smooth	SM	S	Fair	Fair	Not a strong competitor. Spreads by rhizomes. Has rustic seed head.
Brome, 'Blando'	SM	S	Poor	Poor to Good	Grew well on fill at Alturas.

Table 17. Continued

Species	1/ T	A	Stand establishment Tahoe	Alturas	Reaction in mixtures and remarks
Canarygrass, reed (commercial)	M		Fair	NS	Dominated mixture where soil partially wet. Did not grow well in area continuously wet or on dry land.
Clover, white 'Dutch'	SM	SM	Poor	Failed	Grew best alone and on moist or finer textured soils. Too short to compete with tall grasses.
Crownvetch, 'Chemung'	S	S	Poor	Failed	Some plants on fine textured soil of north-facing slope.
Fescue, foxtail	S	S	Poor	Poor	May not persist long.
Fescue, 'Durar' hard	SM	SM	Poor to fair	Poor to fair	Evident in mixtures but dominated by Luna and Tegmar. Best seeded with short grasses. Grew well on compacted soil.
Lupine, sickle-keeled	M		Poor	NS	Not evaluated.
Milkvetch, 'Cicar' and 'Lutana' cicer	SM	SM	Poor	Failed	Best on more moist or fine textured soils. Longevity good. Spreads by rhizomes.
Orchardgrass, 'Latar'	SM	SM	Fair	Poor	Dominated by Luna, Tegmar on dry sites. Requires more moisture.
Orchardgrass, 'Palestine'	SM	SM	Good	Poor	First seeded in mixture in spring 1974. Competing well in early trials
Orchardgrass, 'Pomar'	SM	SM	Poor	Failed	Not competitive with taller grasses, growing fair with shorter ones at Tahoe.

Table 17. Continued

Species	1/ T	A	Stand establishment Tahoe	Alturas	Reaction in mixtures and remarks
Orchardgrass, 'Potomac'	S	S	Good	Poor	Not tested in mixtures
Pea, flat	M		Fair	NS	Attractive flowers. Foliage dies back after frosts and becomes unsightly.
Poppy, California	SM	S	Poor	Poor	First seeded in mixtures in fall 1974.
Rye cereal	SM	S	Good	Good	Dominates perennial grass mixtures but some perennial grasses survive.
Ryegrass, annual		S	NS	Poor	Not seeded in mixtures. Does not persist.
Ryegrass, 'Wimmera 62'	SM	S	Poor to fair	Poor	Some small plants first year. Does not persist.
Sweetclover, annual	S	S	Failed	Failed	Not adapted.
Sweetclover, yellow blossom	SM	S	Fair	Failed	Becomes dominant in moist areas. Grows well in fine textured soils, poorly on granitic. Not recommended as competitive and tall.
Squirreltail		Seed collected at the South Tahoe Airport, and seed increase started at Lockeford PMC in 1974.			
Trefoil, 'Cascade' birdsfoot	SM	S	Poor	Failed	Adds some color in wet areas.
Trefoil, dwarf English	M		Seeded in fall 1974	NS	Not evaluated.
Trefoil, narrowleaf	M		Poor	NS	Grew well in wet areas and on compacted fine textured soil along roadside. Colorful flowers.

Table 17. Continued

Species	1/ T	1/ A	Stand establishment Tahoe	Stand establishment Alturas	Reaction in mixtures and remarks
Wheat, 'Galglass'		S	NS	Poor	Not seeded in mixtures.
Wheat, 'Nugaines'		S	NS	Poor	Not seeded in mixtures.
Wheatgrass, 'Fairway' crested	SM	SM	Fair to good	Good to excellent	Dominated in mixtures by Luna, Tegmar at Tahoe bu not at Alturas.
Wheatgrass, 'Nordan' standard crested	SM	SM	Poor	Poor	Poor establishment may have been due to old seed.
Wheatgrass, 'Amur' intermediate	S		Good	NS	Not seeded in mixtures.
Wheatgrass, 'Greenar' intermediate	SM	SM	Fair	Fair	Not as vigorous as Luna.
Wheatgrass, 'Mandan' intermediate	S		Seeded in fall 1974	NS	Not evaluated.
Wheatgrass, 'Oahe' intermediate	S	S	Good	Good	Not tested in mixtures.
Wheatgrass, 'Tegmar' intermediate	SM	SM	Good	Good	Dominates except for Luna at Tahoe and crested at Alturas.
Wheatgrass, 'Luna' pubescent	SM	SM	Good	Good	Dominates except Tegmar at Tahoe and crested at Alturas.
Wheatgrass, 'Topar' pubescent	S	SM	Fair	Fair	Seedlings not as vigorous as Luna.
Wheatgrass, 'Primar' slender	SM	SM	Poor	Poor	Dominated in mixtures by Luna, Tegmar at Tahoe.
Wheatgrass, 'Sodar' streambank	SM	SM	Poor	Poor	Dominated in mixtures by Luna, Tegmar at Tahoe. Develops slowly.
Wheatgrass, 'Alkar'	S	S	Poor	Poor	Not tested in mixtures.

Table 17. Continued

Species	1/ T	1/ A	Stand establishment Tahoe	Stand establishment Alturas	Reaction in mixtures and remarks
Wheatgrass, 'Critana' thickspike	S	S	Good	Good	Not tested in mixtures.
Wheatgrass, 'Barton' western	S	S	Poor	Poor	Not tested in mixtures.
Wheatgrass, 727 western	SM	SM	Poor	Poor	Dominated by Luna and Tegmar. Would be excellent cover if could get a good stand.
Wildrye, beardless	S		Good	NP	Clone planted.
Wildrye, Volga	S		Poor	NP	Clone planted. Not in mixtures.

1/ Ratings based on single-species seeding.
T = Tahoe Basin and vicinity
A = Alturas
S = Seeded singly
M = Seeded in mixtures
SM = Seeded both singly and in mixtures
NP = Not planted
NS = Not seeded

Table 18. Mixtures of grasses, legumes, and other herbaceous species seeded at various locations on cut and fill slopes from 1970 to 1974 at Tahoe Basin and vicinity and Alturas.

Mixture	% 1/	Location	Year cut (c) and fill (f) 70-71	71-72	72-73	73-74
55 2/ 'Luna' pub. wg.	30	Airport	3c 1f	2c	2c	
'Tegmar' int. wg.	30	Glenbrook to	2c 2f			
'Sodar' stb. wg.	30	Spooner Summit				
Cicer milkvetch	10	Incline Village	1c 1f			
		Hope Valley		2c		
		Alturas		2c 1f	2c 1f	
56 'Luna' pub. wg.	30	Airport	3c 1f	2c	2c	
'Greenar' int. wg.	30	Glenbrook to	2c 2f			
'Sodar' stb. wg.	30	Spooner Summit				
Cicer milkvetch	10	Incline Village	1c 1f			
		Hope Valley		2c		
		Alturas		2c 1f	2c 1f	
57 'Luna' pub. wg.	30	Airport	3c 1f	2c	2c	
'Tegmar' int. wg.	20	Glenbrook to	2c 2f			
'Sodar' stb. wg.	20	Spooner Summit				
'Durar' hard fescue	20	Incline Village	1c 1f			
Cicer milkvetch	10	Hope Valley		2c		
		Alturas		2c 1f	2c 1f	
58 'Luna' pub. wg.	30	Airport	3c 1f	2c	2c	
'Tegmar' int. wg.	20	Glenbrook to	2c 2f			
'Sodar' stb. wg.	20	Spooner Summit				
'Primar' sld. wg.	20	Incline Village	1c 1f			
Cicer milkvetch	10	Hope Valley		2c		
		Alturas		2c 1f	2c 1f	
59 'Luna' pub. wg.	30	Airport	3c 1f	2c	2c	
'Tegmar' int. wg.	20	Glenbrook to	3c 2f			
'Sodar' stb. wg.	20	Spooner Summit				
'Wimmera 62' rg.	20	Incline Village	1c 1f			
Cicer milkvetch	10	Hope Valley		2c		
		Alturas		2c 1f	2c 1f	
60 'Luna' pub. wg.	30	Airport	3c 1f	2c	2c	
'Tegmar' int. wg.	20	Glenbrook to	2c 2f			
'Sodar' stb. wg.	20	Spooner Summitt				
'Fairway' crested wheatgrass	20	Incline Village	1c 1f			
		Hope Valley		2c		
Cicer milkvetch	10	Alturas		2c 1f	2c 1f	

Table 18. Continued

Mixture	% 1/	Location	Year cut (c) and fill (f) 70-71	71-72	72-73	73-74
61 'Luna' pub. wg.	30	Airport	6c 3f	2c	2c	
'Tegmar' int. wg.	20	Glenbrook to	3c 2f			
'Sodar' stb. wg.	20	Spooner Summit				
'Sherman' big bluegrass	20	Incline Village	1c 1f			
		Hope Valley		2c		
Cicer milkvetch	10	Alturas		2c 1f	2c 1f	
62 'Luna' pub. wg.	30	Airport	3c 1f	2c	2c	
'Tegmar' int. wg.	20	Glenbrook to	3c 2f			
'Sodar' stb. wg.	20	Spooner Summit				
'Latar' orch. gr.	20	Incline Village	1c 1f			
Cicer milkvetch	10	Hope Valley		2c		
		Alturas		2c 1f	2c 1f	
63 'Luna' pub. wg.	30	Airport	3c 1f	2c	2c	
'Tegmar' int. wg.	20	Glenbrook to	2c 2f			
'Sodar' stb. wg.	20	Spooner Summit				
'Durar' hard fescue	20	Incline Village	1c 1f			
Sweet clover	10	Hope Valley		2c		
		Alturas		2c 1f	2c 1f	
64 'Durar' hard fescue	10	Airport	3c 1f	2c		
'Tegmar' int. wg.	20	Glenbrook to	2c 2f			
'Sodar' stb. wg.	20	Spooner Summit				
'Pomar' orch. gr.	20	Incline Village	1c 1f			
'Manchar' smooth brome	20	Hope Valley		2c		
'Rambler' alfalfa	10	Alturas				
65 Western wheatgrass	30	Airport	3c 1f	2c		
		Glenbrook to	3c 2f			
'Sodar' stb. wg.	20	Spooner Summit				
'Tegmar' int. wg.	20	Incline Village	1c 1f			
'Durar' hard fescue	20	Hope Valley		2c		
Cicer milkvetch	10	Alturas				
66 'Sodar' stb. wg.	30	Airport		2c		
'Pomar' orch. gr.	30	Hope Valley		2c		
'Durar' hard fescue	30	Alturas		2c 1f	2c 1f	
White 'Dutch' clover	10	Northstar				

Table 18. Continued

Mixture	% 1/	Location	Year cut (c) and fill (f) 70-71	71-72	72-73	73-74
67 'Tegmar' int. wg.	30	Airport	2c	2c		
Western wheatgrass	20	Hope Valley	2c			
'Manchar' smooth brome	20	Alturas		2c 1f	2c 1f	
'Sherman' big bluegrass	20					
'Rambler' alfalfa	10					
68 'Luna' pub. wg.	30	Airport			2c	
'Fairway' crested wheatgrass	20	Alturas			2c 1f	
'Sherman' big bluegrass	20					
'Latar' orch. gr.	20					
Cicer milkvetch	10					
69 Wet area mixtures						
'Greenar' int. wg.	25	Airport	1c			
'Highland' colonial bentgrass	25					
Reed canarygrass	30					
Narrowleaf trefoil	10					
Yellow sweet clover	10					

1/ Percent of 40 pounds per acre, the rate all mixtures were seeded unless otherwise indicated.

2/ Numbers continued from central coastal and Sierra Nevada foothills, Table 3.

Table 19. Growth form, possible use, and expected percent survival of 60 shrubs planted on cut and fill slopes in the central coastal and Sierra Nevada foothills.

Species	1/ Accession number	2/ Growth form	3/ Possible use	4/ Native or exotic	Percent survival 5/ coastal foothills cut	coastal foothills fill	Sierra foothills cut	Sierra foothills fill	Establishment and remarks
Adelia or desert olive	371-65	M	R	N		40		0	Fair in coastal foothills. Deciduous.
Balloon pea	P14329	L		E		0		0	Failed.
Bitterbrush, antelope	237-71	M	R	N	60				Good, but grows slowly.
Bitterbrush, desert	60-69	L	R	N			X		Trials incomplete.
Bladderpod	328-65	L	R	N	50	0		40	Fair, grows slowly.
Buckwheat, California	767-64	L	R B	N	80	20	80	50	Good.
Buckwheat, St. Catherine's lace	261-69	L	R	N		0			Failed.
Buckwheat, sulfur flower	158-72	P-L		N			X		Trials incomplete.
Ceanothus, blue blossom (compacta)	569-64	M	R S	N		25		0	Fair in coastal foothills.
Ceanothus, buckbrush or wedgeleaf	154-68, 99-69 etc.	M	R	N		40	100X	60	Good in Sierra foothills. Mice eat bark.
Ceanothus, Carmel creeper	122-71	P-L	R B	N		0			Poor.
Ceanothus, hybrid	LK-451, LK-450	P		N			X		Trials incomplete.

Table 19. Continued

Species	1/ Accession number	2/ Growth form	3/ Possible use	4/ Native or exotic	Percent survival 5/ coastal foothills cut	coastal foothills fill	Sierra foothills cut	Sierra foothills fill	Establishment and remarks
Ceanothus, Lemmon	109-72	L	R	N			X		Trials incomplete.
Ceanothus, maritime	8-71	P	R	N		0		0	Poor.
Ceanothus, roderickii*	282-70	P-L	R	N			X	0	Poor. Trials incomplete.
Ceanothus, wartleaf	31-71	M	R	N		20	X	40	Fair. Mice eat bark.
Ceanothus, woolyleaf	111-72	M	R	N			X		Trials incomplete.
Chamise	50-71	M	R	N			X		Had difficulties propagating from seed and cuttings.
Cherry, hollyleaf	43-64	T	R S	N			X		Trials incomplete.
Chrysanthemoides monilifera*	343-69	L		E		0			Failed.
Coffeeberry, California	257-66	M	R S	N			0		Fair on droughty soils.
Coyote, brush, prostrate	7-71	P-L	B	N		40		0	Fair in coastal foothills.
Coyote brush, prostrate (Twin Peaks)	6-71	P	B	N		60		0	Good in coastal foothills.
Coyote brush	67-71 761-64 etc.	M	R S	N	90	70	60X	60	Excellent in coastal foothills.
Cypress, Sahara	104-70	M	S?	E			X		Trials incomplete.

Table 19. Continued

Species	1/ Accession number	2/ Growth form	3/ Possible use	4/ Native or exotic	Percent survival 5/ coastal foothills cut	coastal foothills fill	Sierra foothills cut	Sierra foothills fill	Establishment and remarks
Dorycnium suffruticosum*	210-69	L		E		0		30	Poor.
Escallonia, white	237-67	M		E		0		0	Failed.
Flannel bush, dwarf	177-71	L	R	N			X		Trials incomplete.
Gooseberry, rock	184-64	L	R	N			X		Needs further testing.
Manzanita, bearberry	239-71	P		N		30	X		Poor.
Manzanita, bigberry (var. puberula)	454-64	M	R	N		50	X		Fair. Needs further study.
Manzanita, Parry	CALTRANS	M	R	N		60			Fair. Needs further study.
Manzanita, whiteleaf	284-70, LK-66	M	R S?	N		0	80X	50	Good in Sierra foothills. Mice eat bark.
Medic, tree	185-64	L		E		0		0	Failed. Rodents eat.
Melaluca, drooping	3-68	M		E			0		Failed. Froze in Sierra foothills.
Monkey flower	14-71	L	R	N			X		Trials incomplete.
Myrica cordifolia*	310-63	L		E		0		0	Failed. Needs more moisture.
Oleander	46-71	M	S	E		70		0	Good in coastal foothills.

Table 19. Continued

Species	1/ Accession number	2/ Growth form	3/ Possible use	4/ Native or exotic	Percent survival 5/ coastal foothills cut	coastal foothills fill	Sierra foothills cut	Sierra foothills fill	Establishment and remarks
Osteospermum spinescens*	207-69	L		E		70		40	Fair. Needs further testing.
Penstemon, mountain pride	203-72	P-L	R	N			X		Trials incomplete.
Penstemon, Rocky Mountain	Bandera	P-L	B	N		60	X	80	Good. Needs further testing.
Redberry	186-69	M	R	N		0			Needs further testing.
Redbud, California	176-71		R	N			0X		Failed on droughty soil.
Rockrose	312-63	L	B S	E	70	50	80	60	Good. Colorful. Rodents eat bark.
Rockrose, Descanso hybrid	117-71	P-L	B	E			X		Trials incomplete.
Rockrose, sageleaf	335-69	P-L	B	E			X		Trials incomplete.
Rosemary	41-71	P		E		60		40	Fair.
Sage, black	465-64	L	R	N	40	0		0	Poor.
Sage, creeping	282-70, 283-70	P	B	N			X	40	Fair. Possibilities in fire control.
Sagebrush, California	30-71	L	R	N					Trials incomplete.
Sagebrush, Caucasian	92-70	P	B	E	15	15	10X	10	Poor.
Saltbush, Australian	310-69	P	B	E		0		0	Frost killed. Came back from volunteer seed.

Table 19. Continued

Species	1/ Accession number	2/ Growth form	3/ Possible use	4/ Native or exotic	Percent survival 5/ coastal foothills cut	coastal foothills fill	Sierra foothills cut	Sierra foothills fill	Establishment and remarks
Saltbush, Australian	112-70	P	B	E		0		0	Frost killed. Came back from volunteer seed.
Saltbush, Australian	Blend	P	B	E			X	X	Trials incomplete.
Saltbush, desert or allscale	5-65	M	R	N		40	40	80	Good.
Saltbush, fourwing	324-61,173-64	M	R	N	90	80	0	80	Excellent in coastal foothills.
Saltbush, fourwing	2-71(Bridger)	P		N			X	50	Fair.
Saltbush, Nuttall	507-64	P	B			0			Failed.
Saltbush, quailbush	595-64,4-65	M	R S	N		80	X	60	Good. Grows rapidly.
Sheepbush, ruby	348-67	M		E		70		0	Fair. Testing discontinued since frost killed.
Sumac, squawbush	573-64,261-70	L	R	N		10	X		Poor.
Summercypress, prostrate	40-72	L		E		0		0	Failed.
Toyon	663-64	M-T	R S?	N		0			Failed. Needs further testing.
Wolfberry, Anderson	349-67	M	R	N		0		0	Failed.

* Common name not known.
1/ All Pleasanton PMC identification numbers unless otherwise designated.
2/ P = prostrate L = 5' or less in height M = 5-10' in height T = over 10' in height
3/ R = revegetation B = bank planting S = screen planting
4/ N = native E = exotic, not native in California
5/ X = planted but too young to determine survival

Table 20. Exposure, soil series, and soil parent material of 21 shrub planting locations in the north-central coastal and Sierra Nevada foothills from 1972 to 1974.

Location	Exposure		Soil series	Soil parent material
Crystal Springs	1971 Cut	S	Gaviota-like sandy loam	Dominantly sandstone with basalt and serpentine intrusions.
	1971 Fill	S	"	"
	1972 Cut	S	"	"
	1972 Fill	S	"	"
	1973 Fill	NW	Climara clay loam	Serpentine
Plymouth	1971 Cut	W	Auburn very rocky silt loam	Metabasic schist weathered enough to break into sand-size particles.
	1971 Fill	E	"	"
	1972 Cut	W	"	"
	1972 Fill	E	"	"
Ione	1971 Fill	NE	Exchequer very rocky loam	Metasedimentary. Vertically folded rock.
	1972 Cut	SW	Sedimentary rock sand	Sandstone and clay marine sediments. Low fertility.
Missouri Flats	1971 Fill	W	Boomer gravelly loam	Basic igneous rock mixed with gravel.
Shenandoah Valley	1972 Fill	W	Sierra sandy loam	Granitic
Shingle Springs	1973 Cut	SE	Sobranto silt loam	Hard basic schist
Ponderosa Road	1973 Cut	S	Rescue very stony sandy loam	Gabbrodiorite
Sonora	1973 Cut	SW	Auburn loam	Metabasic schist
	1973 Fill	SW+N	"	", plus gravel
Penn Valley	1973 Cut	S	Sierra loam over clay	Granodiorite
	1974 Cut	S	"	"
	1974 Cut	N	"	"
	1974 Cut	N	Trabucco loam	"

Table 21. Shrub species seeded at several locations in the north central coastal and Sierra Nevada foothills and remarks regarding germination and survival.

Species	Type of seedlings 1/	Number of locations	Remarks
Balloon pea	B,C	4	Good germination, no survival.
Bitterbrush, antelope	B,C,S,	7	Fair germination, some survival.
Bladderpod	B,C,S	7	Good germination, persists fairly well but grows slowly.
Buckwheat, California	B,C	6	Good germination, some survival.
Ceanothus, blue blossom	B,C	6	Poor germination, survival questionable.
Ceanothus, buckbrush	B,C,S	7	Very poor germination, survival questionable.
Cotoneaster	C	3	No germination.
Coyote brush	C,S	5	No germination.
Manzanita, bigberry	B,C	4	Poor germination, a few plants.
Manzanita, whiteleaf	C,S	5	No germination.
Rabbitbrush, rubber	C	3	No germination.
Rockrose	B,C	7	Good germination, some survival.
Sage, black	B,C,S	7	Fair germination, some survival.
Sage, creeping	C,S	5	No germination.
Sagebrush, big	C	3	No germination.
Saltbush, Australian	S	2	No germination from old seed. Fresh seed is known to germinate readily.
Saltbush, fourwing	B,C,S	7	Fair germination, some survival.
Saltbush, quailbush	B,C,S	7	Poor germination, some survival.

Table 21. Continued

Species	Type of seedlings 1/	Number of locations	Remarks
Toyon	S	1	No germination from old seed. Fresh seed known to germinate readily.
Wolfberry	B,C,S	7	Fair germination, some survival.

1/ B = broadcast on rough seedbed
C = seed in small contour furrows
S = spot seeded

Table 22. Exposure, soil series, and soil parent material of 19 shrub planting locations in the Tahoe Basin and vicinity from 1972 to 1975.

Location	Exposure		Soil series	Soil parent material
El Dorado Co. Airport South Lake Tahoe	1972 Fill	E	Jabu sandy loam variant	Granitic alluvium
	1972 Fill	E	"	"
	1973 Fill	E	"	"
	1973 Fill	E	"	"
	1974 Fill	E	"	"
Hope Valley	1974 Cut	SE	Meeks stony loamy coarse sand	Glacial granitic
Northstar at Tahoe	1973 Cut	S	Tahoma sandy loam	Jorge=basalt; Tahoma=andesitic, or andesitic tuff
	1973 Cut	NW	"	"
	1973 Fill	NW	"	"
	1973 Fill	NW	"	"
	1973 Fill	SE	"	"
	1973 Cut	NE	"	"
	1974 Cut	S	"	"
	1974 Fill	S	"	"
Truckee	1972 Fill	SE	Fugawee and Trojan sandy loam	Andesitic
Highway 88	1974 Cut	SW	Chaix coarse sandy loam	Granitic
	1974 Cut	S	Windy cobbly sandy loam	"
	1974 Cut	N	"	"
	1974 Cut	S	Series loamy coarse sand	Glacial, granitic, and andesitic

Table 23. Growth form, possible use, and expected percent survival of 47 shrub species planted in the Tahoe Basin and vicinity.

Species	1/ Accession number	2/ Growth form	3/ Native or exotic	4/ Possible use	Percent survival	Establishment and remarks
Adelia or desert olive	371-65	M	NN		0	Not adapted.
Bayberry, northern	250-71	M	NN		0	Poor.
Bitterbrush, antelope	237-71	M	N	R B	90	Good. Semi-deciduous.
Buckwheat, sulfur flower	158-72	P	N	R B	80	Good. Colorful flowers.
Ceanothus, buckbrush or wedgeleaf	154-68, 99-69 etc.	M	NN		50	Fair. Poor growth.
Ceanothus, Fresno mat	123-71	P	NN	B	5	Poor.
Ceanothus, mountain whitethorn or snowbush	120-69-201-70 139-72	L-M	N	R B	80	Good, need to improve.
Ceanothus, squaw carpet	87-71,231-71	P	N	B R	40	Fair, need to improve.
Ceanothus, tobacco brush or snowbush	140-72	M	N	R	40	Fair, need to improve.
Dogwood, redosier or American	179-70	M	N	R	60	Good. Deciduous.
Ephedra, green or Morman tea	752-64	L	NN	R	25	Poor.
Juniper, 'Emerald Sea' shore	LK-55	L	E	B	0-80	Seems too cold.

Table 23. Continued

Species	1/ Accession number	2/ Growth form	3/ Native or exotic	4/ Possible use	Percent survival	Establishment and remarks
Leucodendron nutans*	202-69	L	E		0	Not adapted. Too cold.
Lilac, common	186-71	M	E		80	Good. Poor on granite.
Locust, 'Arnot' bristly	9-71	M	E		10	Poor. Deciduous.
Manzanita, bearberry or kinnikinnick	239-71	P	N E	B	50	Fair.
Manzanita, greenleaf	207-72,72-73	M	N	R	75	Good.
Manzanita, pine mat	LK-124,LK-73	P	N	R	40	Fair, need to improve.
Oak, huckleberry	193-70	L-M	N	R	0	Poor, need to improve.
Olive, autumn	226-71,158-72	M	E		50	Not well adapted.
Olive, Russian	252-70	M	E		0	Poor. Deciduous.
Osteospermum spinescens*	207-69	L	E	B	0	Not adapted.
Pea shrub, Siberian	9-72	M	E		90	Excellent. Deciduous.
Pear, Bradford	4-70	M	E		40	Fair. Deciduous.
Penstemon, 'Bandera' Rocky Mountain	33-69	P	NN	B	90	Good. Colorful. Stalky.

Table 23. Continued

Species	1/ Accession number	2/ Growth form	3/ Native or exotic	4/ Possible use	Percent survival	Establishment and remarks
Penstemon, mountain pride	203-72,LK-197	P	N	B R	90	Variable. Colorful.
Rabbitbrush, rubber	247-71,204-72	L	N	R	90	Variable, need to improve.
Rhamnus rubra*	177-69	L	N	R	40	Fair. Semi-deciduous.
Rockrose	312-63	L	E		0	Not adapted. Too cold.
Rose, Nutkana	578-64	L	NN		0	Poor.
Rose, Wichura	206-66	P	E	B	80	Good.
Rose, Woods	272-71	L-M	N	B	80	Good.
Sagebrush, big	21-72	L	N	R	90	Excellent. Competes well with grasses.
Sagebrush, Caucasian	92-70	P	E	B	80	Good.
Saltbush, desert or allscale	175-72	M	NN		0	Poor. Questionable value.
Saltbush, fourwing	324-61	M	NN	S	0-60	Variable. Questionable value.
Saltbush, fourwing (Bridger)	2-71	L	NN	B	40	Fair. Foliage is sparse.
Saltbush, Gardner	162-69	P	NN	B	5	Poor. Questionable value.

Table 23. Continued

Species	1/ Accession number	2/ Growth form	3/ Native or exotic	4/ Possible use	Percent survival	Establishment and remarks
Saltbush, Nuttall	507-64	P	NN	B	7	Poor. Questionable value.
Snowberry	207-70	L	N	R	60	Fair.
Sumac, squawbush	261-70	L	NN		10	Poor. Deciduous.
Summercypress, prostrate	243-70,40-71	L	E	B	50	Fair. Browns off.
Twinberry, honeysuckle	LK-173	L	N	B	?	Poor. Deciduous.
Willow, dwarf arctic	57-71	M	E	B	90	Variable.
Willow, slender purple	48-71	M	E	B	90	Variable.
Wolfberry, Anderson	349-67	M	NN		0	Not adapted. Too cold.

* Common name not known.
1/ All Pleasanton PMC identification numbers unless otherwise designated.
2/ P = prostrate L = 5' or less in height M = 5-10' in height T = over 10' in height
3/ N = native NN = not native in Tahoe Basin E = exotic, not native in the United States
4/ R = revegetation B = bank planting S = screen planting

Table 24. Methods of seed cleaning, seeds per pound, and acceptable purity and germination for shrubs potentially adapted to revegetation of California highway slopes.

Species	Seed cleaning methods	Seeds per/pound	Acceptable purity (%)	Acceptable 1/ germination (%)	Years with good germination
Arctostaphylos nevadensis	Depulp, dry, fan	30,000	95	2	5
Artostaphylos patula	"	11,000	95	40	5
Arctostaphylos uva-ursi	"	37,000	95	40	5
Arctostaphylos viscida	"	38,000	95	30	5
Artemisia californica	Hammermill, screen, fan	5,044,000	10	30	2
Artemisia tridentata	"	2,500,000	10	30	2
Atriplex canescens	De-wing, fan	56,000	95	50	5
Atriplex lentiformis	Fan	500,000	90	50	5
Atriplex polycarpa	Fan	450,000	70	30	3
Atriplex semibaccata	Dry, fan	75,000	95	50	1
Baccharis pilularis consanguinea	Hammermill	8,200,000	10	50	1
Ceanothus cordulatus	Hammermill, fan, float	141,000	90	70	5
Ceanothus cuneatus	"	56,000	90	60	5
Ceanothus integerrimus	"	58,000	90	60	5
Ceanothus lemmonii	"	118,000	90	70	5

Table 24. Continued

Species	Seed cleaning methods	Seeds per/pound	Acceptable purity (%)	Acceptable 1/ germination (%)	Years with good germination
Ceanothus papillosus	Hammermill, fan, float	102,000	90	70	5
Ceanothus prostratus	"	42,000	90	70	5
Ceanothus roderickii	"	84,000	90	70	5
Ceanothus velutinus	"	120,000	90	70	5
Cercis occidentalis	Hammermill, fan	12,000	95	50	5
Chrysothamnus nauseosus	Hammermill	700,000	10	75	1
Cistus villosus	Hammermill, screen, fan	560,000	95	50	5
Eriogonum fasciculatum	"	500,000	90	70	5
Eriogonum umbellatum	"	168,000	80	50	3
Fremontodendron californica decumbens	"	?	?	?	
Heteromeles arbutifolia	Depulp through screen while fresh	24,000	50	70	2
Isomeris arborea	Hammermill	5,000	95	70	5
Mimulus aurantiacus	Hammermill, fan	16,000,000	90	30	?
Penstemon newberryi	"	1,500,000	90	30	5

Table 24. Continued

Species	Seed cleaning methods	Seeds per/pound	Acceptable purity (%)	Acceptable 1/ germination (%)	Years with good germination
Penstemon strictus	Hammermill, fan	355,000	?	?	5
Prunus ilicifolia	Depulp, dry, fan	200	95	50	?
Prunus emarginata	"	1,800	95	5	?
Purshia tridentata	Fan, use de-winger	15,000	90	70	5
Rhamnus californica	Depulp, dry, fan	4,000	90	50	5
Rhus trilobata	"	19,000	90	?	5
Ribes quercetorum	"	128,000	95	20	5
Rosa woodsii ultramontana	"	43,500	95	10	5
Salvia mellifera	Hammermill, fan	467,000	95	40	5
Salvia sonomensis	"	550,000	95	50	5

1/ Acceptable germination of treated seed, if treatment is necessary.

Table 25. Flowering, maturing dates, and methods of seed collection for shrubs potentially adapted to revegetation of California highway slopes.

Species	Flowering	Maturity	Methods of seed collection
Arctostaphylos nevadensis	May-Jul	Aug-Oct	Handpick into containers
Arctostaphylos patula	Apr-June	Aug-Oct	"
Arctostaphylos viscida	Feb-Apr	Jun-Sept	"
Artostaphylos uva-ursi	Mar-June	Sept-Nov	"
Artemisia californica	Aug-Dec	Oct-Feb	Handstrip into containers
Artemisia tridentata	Aug-Oct	Oct-Dec	"
Atriplex canescens	Jun-Aug	Oct-Dec	". Mechanical harvest of cultivated crop
Atriplex lentiformis	Aug-Oct	Nov-Jan	Handstrip into containers
Atriplex polycarpa	Jul-Oct	Nov-Dec	"
Atriplex semibaccata	Apr-Dec	May-Jan	Shake into canvas underneath
Baccharis pilularis consanguinea	Aug-Dec	Oct-Jan	Handstrip into containers
Ceanothus cordulatus	May-Jul	Jul-Sept	Handpick into containers
Ceanothus cuneatus	Mar-May	Apr-Jun	"
Ceanothus integerimus	May-June	Jun-Jul	"

Table 25. Continued

Species	Flowering	Maturity	Methods of seed collection
Ceanothus lemmonii	Apr-May	May-Jun	Handpick into containers
Ceanothus papillosus	Apr-May	May-Jun	"
Ceanothus prostratus	Apr-Jun	Jun-Aug	"
Ceanothus roderickii	Apr-May	May-Jun	"
Ceanothus velutinus	Apr-Jul	Jul-Sept	"
Cercis occidentalis	Feb-Mar	Aug-Jan	"
Chrysothamnus nauseosus	Aug-Oct	Oct-Nov	Handstrip into hoppers or containers
Cistus villosus	Apr-May	May-Jul	Handpick into containers
Eriogonum fasciculatum	May-Oct	Jun-Nov	Handstrip into containers
Eriogonum umbellatum	Jul-Aug	Aug-Sept	"
Fremontodendron californica decumbens	May	Aug-Sept	"
Heteromeles arbutifolia	Jun-Jul	Dec-Jan	"
Isomeris arborea	Most of year	Jul-Sept	" or knock onto canvas
Mimulus aurantiacus	Mar-Aug	Jul-Sept	Handstrip into containers
Penstemon newberryi	Jun-Aug	Jul-Sept	Handpick into containers

Table 25. Continued

Species	Flowering	Maturity	Methods of seed collection
Penstemon strictus	May-Jul	Jul-Sept	Machine harvest (commercially grown)
Prunus ilicifolia	Apr-May	Jul-Sept	Knock on canvas or handpick into containers
Prunus emarginata	Apr-May	Jul-Sept	"
Purshia tridentata	May-Jul	Aug-Oct	Knock into hopper or canvas
Rhamnus californica	May-Jul	Jul-Sept	Knock on canvas or handpick into containers
Rhus trilobata	Mar-Apr	Aug-Nov	Handpick into containers
Ribes quercetorum	Mar-May	Apr-Jun	Knock into canvas underneath
Rosa woodsii ultramontana	Jun-Aug	Aug-Oct	Knock or beat into hoppers or containers
Salvia mellifera	Apr-Jul	Jul-Aug	Handstrip into containers
Salvia sonomensis	May-Jun	Jul-Aug	"

Table 26. Dimensions, advantages, and disadvantages of various containers for planting out shrubs on California highway slopes.

Container system	Container dimensions (inches)	Container volume (cu. inches)	Containers per unit	Advantages	Disadvantages
Gallon cans**	6 (dia) x 7 (deep)	231.0	1	Use for shrubs older than one year.	Not adapted to large scale plantings. Root spiraling.
Tarpaper bands**	2-3/4 x 2-3/4 x 8	60.5	19/ft 2	Can fit into existing flats trays, etc.	Root egress from individual liners into others. Must use heavy potting mix with soil included. not reusable.
Spencer-Lemaire**	2 x 2 x 8	30.0	4/book 24/ft 2	Reusable for 2-3 years. Grooves in containers. Train roots to prevent spiraling. No root egress, efficient "air pruning" at bottom of container.	Tops of book planters exposed to sun can decompose in one year.
Styroblock 8*	1.55 x 6	8.0	80/block or 41/ft 2	Reusable for 3 years or more depending on abuse. Effective "air pruning." Blocks are light easy to fill with potting mix.	Cannot be roughly treated. Plants may not pull off blocks for planting. Hard to transplant into containers.
RL single cell*	1 x 6.3	4.0	200/tray or 100/ft 2	Reusable, durable. Containers come with custom made trays. Light, easy to fill with potting mix. Effective "air pruning."	Small cavities, hard to transplant into containers.

Table 26. Continued

Container system	Container dimensions (inches)	Container volume (cu. inches)	Containers per unit	Advantages	Disadvantages
Japanese paper pot+	1.5 x 6.0	8.6	336/set or or 98/ft 2	Inexpensive	Root egress, not reusable. Made from paper.
Jiffy 7 peat pots* 1/	2-1/2 x 3-1/8	11.1	23/ft 2	Outplant plant and container. Fit pots into existing flats, trays. Lightweight. Easy to transplant and outplant.	Not reusable. Container may draw moisture away from plant in wild (wick-effect). Depth of pot one-half of others.

** Containers outplanted in field tests by PMC personnel.
* Containers not fully tested or used extensively at PMC.
+ Not tested by PMC.
1/ The Jiffy 7 peat pot is unique in that the pot is a pellet made completely of peat with fertilizer added, enclosed in a plastic mesh and compressed. The pellets are simply soaked in water and they expand into pots.

Table 27. Suggested containers and potting mixtures used in propagating shrubs for planting on California highway slopes.

Situation	Container	Media	Remarks
1. Growing seedlings in flats for transplanting	NA	1/3 perlite 1/3 peat moss 1/3 vermiculite limed to pH 6.0	Soilless. Little trouble with damping off. Good root development in mix.
2. Landscape plantings	Gallon cans or larger	1/3 soil 1/3 peat moss 1/3 perlite	Can substitute cheaper media such as bark or sawdust for peat moss or perlite.
3. Revegetation mass plantings	Root trainers (book planter) Styroblock 8's RL single cells	1/3 vermiculite 1/3 peat moss 1/3 perlite limed to pH 6.5	Very light. Can use dibble planters for outplanting. Can use sterilized native soil in mix in small amount.
4. Rooting cuttings under mist	NA	perlite	Very well drained.
5. Rooting cuttings in covered frame in lath or greenhouse	NA	1/2 perlite 1/2 vermiculite	Well drained, but retains moisture well.

Table 28. Propagation requirements of shrubs potentially adapted to revegetation of California highway slopes.

Species	Origin	Adaptation	Propagation techniques Easy to propagate	Anticipated plants per pound of seed or % rooting
Artctostaphylos patula greenleaf manzanita	native	high elevation	Acid-scarify 2+ hours, cold-stratify 90 days, 50% germination. Water plants infrequently.	3,000
Arctostaphylos viscida whiteleaf manzanita	native	foothills	Seed. Acid-scarify 2+ hours, cold-stratify 30 days, 33% germination. Water plants infrequently.	5,000
Arctostaphylos uva-ursi bearberry	native	foothills and high elevation	Seed. Acid-scarify 2+ hours, cold-stratify 60 days, 50% germination. Tip cuttings in late November. Available commercially.	7,000 70%
Artemisia californica coastal sagebrush	native	foothills	Tip cuttings from May to July.	70%
Artemisia tridentata big sagebrush	native	high elevation	Seed. No treatment. Requires good ventilation to avoid crown rooting in containers.	25,000
Artemisia caucasica caucasus sagebrush	USSR	high elevation	Tip cuttings from July to October. Requires good ventilation and infrequent waterings.	90%
Atriplex canescens fourwing saltbush	native	foothills	Seed. Remove utricles (de-wing).	8,000
Atriplex lentiformis quailbush	native	foothills	Seed. No treatment.	50,000

Table 28. Continued

Species	Origin	Adaptation	Propagation techniques Easy to propagate	Anticipated plants per pound of seed or % rooting
Atriplex polycarpa desert saltbush	native	foothills	Seed. No treatment.	30,000
Atriplex semibaccata Australian saltbush	Australia	foothills	Seed. Use fresh seed.	15,000
Baccharis pilularis consanguinea coyote brush	native	foothills	Seed. Use fresh seed.	80,000
Ceanothus cordulatus mountain whitethorn	native	high elevation	Seed. Acid-scarify seed 30 minutes, treat with 250 ppm GA, 75% germination. Water plants infrequently.	30,000
Ceanothus cuneatus buckbrush	native	foothills	Seed. Acid-scarify seed 30 minutes, treat with 500 ppm GA, 70% germination. Water plants infrequently.	15,000
Ceanothus integerrimus deer brush	native	mid-elevation	Seed. Acid-scarify seed 30 minutes, treat with 750 ppm GA, 70% germination. Water plants infrequently.	15,000
Ceanothus lemmonii Lemmon ceanothus	native	mid-elevation	Seed. Acid-scarify 20 minutes, treat with 500 ppm GA, 70% germination. Water plants infrequently.	30,000
Ceanothus papillosus wartleaf ceanothus	native	mid-elevation	Seed. Acid-scarify 20 minutes, treat with 500 ppm GA, 70% germination. Water plants infrequently.	30,000

Table 28. Continued

Species	Origin	Adaptation	Propagation techniques Easy to propagate	Anticipated plants per pound of seed or % rooting
Ceanothus prostratus squaw carpet	native	high elevation	Seed. Acid-scarify 30 minutes, treat with 250 ppm GA, 70% germination. Water plants infrequently.	10,000
Ceanothus velutinus snowbush ceanothus	native	high elevation	Seed. Acid-scarify 30 minutes, treat with 250 ppm GA, 80% germination. Water plants infrequently.	25,000
Cercis occidentalis redbud	native	foothills	Seed. Acid-scarify 20 minutes, cold-stratify 60 days legume, may want to use native soil.	3,000
Chrysothamnus nauseosus rubber rabbitbush	native	high elevation	Seed. Use fresh seed.	15,000
Cistus villosus rockrose	Europe	foothills	Seed. No treatment.	150,000
Eriogonum fasciculatum California buckwheat	native	foothills	Seed. No treatment.	100,000
Eriogonum unbellatum sulfur flower buckwheat	native	high elevation	Seed. No treatment.	50,000
Heteromeles arbutifolia toyon	native	foothills	Seed. Use fresh seed or cold-stratify one year old seed for 30 days.	6,000
Isomeris arborea bladderpod	native	foothills mid-elevation	Seed. No treatment.	2,500

Table 28. Continued

Species	Origin	Adaptation	Propagation techniques Easy to propagate	Anticipated plants per pound of seed or % rooting
Mimulus aurantiacus bush monkeyflower	native	foothills mid-elevation	Seed. No treatment.	1,000,000
Nerium oleander oleander	native	foothills	Cuttings taken in fall, rooted in water.	75%
Penstemon newberryi mountain pride	native	high elevation	Tip cuttings from August through November.	90%
Penstemon strictus 'Bandera' Rocky Mountain	New Mexico	foothills high elevation	Seed. No treatment.	70,000
Prunus ilicifolia hollyleaf cherry	native	foothills	Seed. Use fresh seed. Seed in flats and transplant to containers.	50-100
Purshia tridentata antelope bitterbrush	native	mid, high elevation	Seed. Scrub seed in running water, cold-stratify 15-30 days, depending on where collected.	4,500
Rhamnus californica California coffeeberry	native	foothills	Seed. Use fresh seed. Cold-stratify one year old seed 30 days. Seed in flats and transplant to containers.	1,000
Rhus trilobata squaw bush	native	foothills	Seed. Acid-scarify 2+ hours, cold-stratify 60 days.	3,000
Rosa wichuriana Wichuria rose	China	high elevation	Softwood cuttings from early spring to late summer. Available commercially from Midwest.	75%

Table 28. Continued

Species	Origin	Adaptation	Propagation techniques Easy to propagate	Anticipated plants per pound of seed or % rooting
Salix purpurea gracilis slender willow	USSR	high elevation	Hardwood cuttings in winter.	90%
Salix purpurea nana dwarf arctic willow	USSR	high elevation	Hardwood cuttings in winter.	90%
Salvia mellifera black sage	native	foothills	Seed. No treatment.	50,000
Salvia sonomensis creeping sage	native	foothills	Seed. Treat with 500 ppm GA.	50,000
Syringa vulgaris common lilac	Europe	high elevation	Seed. Cold-stratify 60 days.	50,000

Table 28. Continued

Species	Origin	Adaptation	Propagation techniques Difficult to propagate (or not fully tested)	Anticipated plants per pound of seed or % rooting
Arctostaphylos nevadensis pinemat manzanita	native	high elevation	Seed. Acid. scarify 2+ hours, cold-stratify 90 days, gives only 2% germination. Cuttings taken late fall rooted 60% in sweatbox. Transplanting has been difficult. Susceptible to disease from overwatering.	300-500 40%
Ceanothus roderickii Roderick ceanothus	native	foothills	Seed. Acid-scarify 20 minutes, treat with 500 ppm GA, give 80% germination. Transplanted seedlings suffered 10% mortality from disease. Problem may increase on larger scale.	3,000
Fremontodendron californica decumbens flannel bush	native	foothills	Seed. Acid-scarify 10 minutes, cold-stratify 60 days, gives fair germination. Not fully tested.	unknown
Kochia prostrata summercypress	USSR	foothills high elevation	Seed. Problem of poor quality seed. Not fully tested. Sporadic germination.	unknown
Ribes quercetorum rock gooseberry	native	foothills	Seed. Cold-stratify 60 days, gives sporadic germination. Rootssuckers dug in winter. Had 75% survival in gallon cans.	unknown
Rosa woodsii ultramontana Woods rose	native	high elevation	Seed. Cold-stratify 90 days. Gives poor germination. Softwood cuttings taken in May-June, root well. Not fully tested.	500 75%
Symphoricarpos vaccinoides snowberry	native	high elevation	Seed. Very poor luck with seed. Hardwood cuttings root well. Not fully tested.	50%

APPENDIX B

Herbaceous Seeding Guide For California

HERBACEOUS

SEEDING GUIDE FOR CALIFORNIA

by

MAJOR LAND RESOURCE AREAS

Developed for

THE CALIFORNIA DEPARTMENT OF TRANSPORTATION
OFFICE OF LANDSCAPE AND ARCHITECTURAL DESIGN

as part of the

PLANT MATERIALS STUDY

by

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

Lockeford, California

George Edmunson

Project Leader

Revised 4/10/75

FOREWORD

The following seeding recommendations are mainly for the design of protective soil covers for erosion control, but they are also useful for fire control, weed control and aesthetics. The recommendations are considered fundamentally sound but are not to be considered final. Recommendations for Major Land Resource Areas 14, 18, 21, and 22 are the result of experience and extensive trials in the Plant Materials Study. These trials have been monitored for four years or less, too brief to be considered final since the vegetative covers continue to change.

The seeding recommendations are designated according to Major Land Resource Areas (MLRA). Throughout each MLRA, environmental conditions are similar in a broad sense, but ranges of climatic, topographic, and soil conditions do occur that can produce some variation in plant responses. In many instances, boundaries separating MLRA's are arbitrary and transitions gradual. Although the Major Land Resource Areas are distinct, several resource area separations are made within the same broad climate such as in the Mediterranean climate. As a result of similar climate, several grasses and legumes were found to be superior for erosion control in more than one resource area, so it was possible to combine the seeding recommendations. Thus, recommendations are combined for Resource Areas 14, 15, 17, and 18, all in the Mediterranean climate of central and northern California, as are those for Resource Areas 5 and 22, two higher elevation mountainous areas in central and northern California.

Except for a few instances, soils have not been differentiated in these recommendations. There are two main reasons. First, in most major highway construction jobs, the cut and fill slopes were largely of parent material from below the soil horizon. It would be better to tie plants to parent material than to soils. Secondly, the grasses and legumes tested, particularly annuals, do not seem highly selective of parent materials, and grew similarly on the parent materials tested except for the widespread serpentines and the highly acid sedimentary material at Ione.

Exposures were not separated because growth of plants was about equal whether the slope was northerly or southerly. Some other interesting divisors were noted however. For example, at lower elevations, on highly compacted fill material along the highway roadbed, 'Blando' brome flourished but not barley. Also, 'Durar' hard fescue grew well at higher elevation on compacted soils but 'Luna' pubescent wheatgrass did not. Most annual species thrived under fertilization on cut slopes at lower elevations. Perennial grasses also grew well on cuts having soft or vertically fractured soil material so the roots could penetrate. Otherwise, the perennials favored fill material. The legume 'Lana' vetch persisted best on deeper soils; with rose clover, best on shallow cut slopes.

Although the seeding recommendations were not separated by soils within a MLRA, some separations were made by average annual fainfall. Although seeding recommendations were separated by elevation in the

southern California mountains, they were not separated in the Sierra Nevada or in the Siskiyou-Trinity areas. This was due to changes in latitude and plant species for the same elevation along the western slope of the Sierra Nevada range. Here the lower ponderosa pine belt was used as a distinct area to make seeding recommendations as well as an area to divide the Mediterranean climate from the colder climate of the higher elevations.

Purity and germination figures shown beside the species are based mainly on minimum seed certification requirements (where available). People in the seed market do not consider these figures to be unrealistically high. These standards should be adhered to for insurance that inferior seed will not place limitations on the results attainable. This does not mean that the seed necessarily be certified, only that it meet certification purity and germination requirements as well as other requirements stipulated in the California Seed Act. The species in the recommendations are usually available commercially, although seed supplies do fluctuate erratically.

THE BOTANICAL NAMES IN THE RECOMMENDATIONS ARE FOLLOWED BY VARIETAL (CULTIVAR) NAMES IN SINGLE QUOTES, THEN BY THE COMMON NAMES IN PARENTHESES.

One benefit from publishing these recommendations would be to provide the designer and those in the commercial seed market with a list of species considered to be superior. Hopefully, these species will serve as an adequate base until sufficient work is done for the list to be expanded.

Inoculation is recommended for all legume seed listed in the guide. Pellet inoculation is the recommended method described in "Pellet Inoculation of Legume Seed," Bulletin AXT-280, University of California, Agricultural Extension Service.

The basic seeding rate for a mixture of small seeded grasses and legumes was 40 pounds per acre. For barley, a large seeded species used mainly for rapid cover, the rate was 180 pounds per acre. These rates can be reduced or raised 25% depending on the erosion hazard. For example, on rocky slopes the amount can be reduced; on sandy or otherwise erosive slopes or in areas where rodents or birds carry away the seed, particularly when early seedings are made, the rate can be increased by at least 25%.

What to Seed

Suggestions for seedings are outlined in the following guide. These include herbaceous species, seeding rates, minimum purity and germination requirements, and fertilizer recommendations. Minimum purity

and germination requirements were used instead of "pure live seed" (PLS) 1/ requirements, primarily to hold minimum germination requirements to a high level.

Table 29, at the end of this guide, lists substitute species to use when seed of the desired species is not available or too costly, along with growth, seed characteristics, average number of seeds per pound and estimated cost of the recommended species in the fall of 1974.

All species in the recommendations have been tested on highway slopes (except veldtgrass used in southern California), most of them repeatedly. They have not always been tested in the resource area in which they are recommended and this is noted in the recommendations. There is usually a choice of herbaceous seeding mixtures including "perennial," "annual," and "rapid cover" mixtures. The selection of a mixture to use in a MLRA has been left to the judgment of the designer. Following are some guidelines to use.

Perennial mixtures. At lower elevations, the perennial mixtures are designed for slopes without a dritical erosion hazard or erosive slopes that are well strawed for soil protection. Generally, perennial species develop much more slowly than annuals. Perennial mixtures are more desirable for fire control as they are shorter and stay green longer. They may be more aesthetically pleasing for the same reasons. Good stands provide for long-term erosion control that keeps out weeds. Perennial mixtures are not fully tested at lower elevations. While they show promise for fire control, aesthetics, and long-term erosion control, in the lower elevations they need extensive testing and monitoring to establish their limits of use. Optional species are crimson clover and California poppy to add color, and 'Blando' brome to improve the vegetative cover for erosion control.

At higher elevations perennial mixtures are usually seeded on all slopes. Should cereal rye be seeded for a quick cover, and perennial grasses mixed with it, there is no guarantee the perennial grasses will survive the competition.

Annual mixtures. Annual mixtures are rapid growing for erosion control. The stands are dense, have a relatively high fuel volume, and often become unsightly when mature. Mixtures that include 'Blando' brome, 'Wimmera 62' ryegrass, and 'Lana' vetch, rapidly develop into dense covers well adapted to erosive slopes; those with 'Blando' brome and rose clover are particularly adapted to use on shallow or rocky slopes without a great erosion hazard. On such slopes, 'Blando' brome and rose clover should persist and provide adequate protection. Addition of flowers such as lupines or California poppy is optional, there

1/ Pure live seed (PLS) is expressed as a percentage. PLS is determined by multiplying the percentage of pure seed (P) by the percentage of germination (G) and dividing by 100. The amount of seed to apply per acre can be determined by substituting in the following formula:

$$\frac{\text{Amount of pure live seed required per acre (lbs/ac)}}{\text{PLS or (P X G} \div 100)} = \text{Amount to seed (lbs/ac)}$$

being no assurance they will always grow or persist. Poppies and lupines are often found growing naturally on steep rocky areas and on gravelly or sandy areas with lesser slopes. If seeded in such areas, they may persist; otherwise they may best be seeded without grasses on non-erosive sites to provide maximum assurance of obtaining a stand.

Rapid cover. Generally, a mixture for "rapid cover" would be used where erosion hazard is critically high, such as on the slopes with sandy erosive soils found around Watsonville, or where the critical watersheds lie above a municipal water supply such as Crystal Springs Reservoir. These covers include rapid developing annuals such as barley or ryegrass along with 'Lana' vetch plus 'Blando' brome added to increase persistence. The suggested seeding rates for rapid cover might seem high, but in absence of statistics to the contrary, high rates are considered insurance against possible erosion, sedimentation and damage to structures.

When to Seed

Determinations of when to seed for erosion control can be made best by people who have experience with erosion control seedings in the locality. In absence of such experience fair results can be obtained by interpreting the weather data from published sources (1). A knowledge of the general as well as of the local climate facilitates making decisions about when to seed. These decisions are not difficult to make. Below are some rules of thumb to follow.

Low elevations in the Mediterranean climate, the northern California redwood belt, in timbered areas at lower elevations, and under the influence of the Mediterranean climate. These should be seeded after June and before January 1, preferably in September. Except in low rainfall areas, there is usually a long mild winter for the seeds to germinate and the plants to develop. However, frost heaving is a severe problem on northerly slopes at higher, colder elevations, particularly on soils with a high silt content. Straw mulching will provide considerable protection where frost heaving occurs. Spring seedings can be considered but would be risky because of the vagaries of the weather--the rainy season may extend too near the summer drought before seeding can be completed or there may be no rain after seeding in the spring.

High elevations in the mountain and continental climate. Seeding can be made from July to snowfall or in the spring, except in areas of low rainfall where spring seedings are questionable because of the lesser chance of spring rains. The chance of success from broadcast seeding at higher elevations is less than at lower elevations because germination is usually in the spring and the spring may be dry. A favorable period for germination after snowmelt may be limited to a

(1) Climatological Data for California. U.S. Department of Commerce in cooperation with the Department of Water Resources, State of California.

few days before the soil surface drys. It is estimated that if there is consistently less than a 12-day wet period (either from rainfall, shade, or wetness after snowmelt) the chances are slim of getting hydromulch seedings established, in which event, every effort should be made to get the seed into the soil.

How to Seed

Seed should be placed in the soil for best results. It should be placed below depth of rapid surface drying and into the area where moisture from winter rains or snow normally remains for several weeks. At lower elevations, seed broadcast on the soil surface, and particularly on a rough seedbed, has a good chance of germinating during the long mild winter. But at higher elevations, the winter is too cold for germination and except during long rainy periods in the spring or on relatively moist sites, seed on the soil surface dries too fast to germinate.

Fertilizer is necessary for rapid growth of grasses and legumes on most cut and fill slopes. Nitrogen fertilizer always seems needed; sometimes phosphate or sulfur, rarely another element. Ammonium phosphate sulfate fertilizer is commonly used, supplying most of the deficient elements in soils. Soil scientists familiar with fertilizer requirements in an area are excellent contacts for fertilizer needs. They should be consulted, particularly on large construction jobs. At lower elevations, 500 pounds per acre of ammonium phosphate sulfate fertilizer 16-20-0 has been commonly applied at the time of seeding with subsequent accelerated growth and a mass of vegetation. This amount can be lowered to 400 pounds with little loss in growth or efficiency of cover, or reduced to 300 pounds on slopes where the soils are stony and not erosive. Fertilizer has been reduced for lower rainfall areas in an attempt to balance the fertilizer requirements of herbaceous species to the lower rainfall.

Mulches are valuable in erosion control seedings, particularly straw and wood-fiber mulches. A straw mulch is particularly beneficial at higher elevations where it protects the seed from drying. Punching straw into the soil which leaves punchholes for the seed to fall into is recommended whenever practical particularly on coarse textured soils. Wood-fiber mulch provides some protection against seed drying, some protection to the soil from beating raindrops, a possible but not positive way to hold seed on steep slopes and, when dyed, to outline the area seeded. At higher elevations where the soil surface dries quickly the amount of wood-fiber mulch can be increased from 1,500 to 3,000 pounds per acre (air-dry weight) to help seed from drying so it can germinate, but the benefit is not great. This increase is not necessary at lower elevations particularly in rough seedbeds. At lower elevations, wood-fiber mulch is not always necessary for good germination, particularly in early seedings where the slopes are rough and the surface loose. On slopes marked with the cleats of tracklayer tractors, seed will fall into the creyices and stands will equal or be better than those from drilling or mulching.

Tentative suggestions for treating toxic and problem soils.

The soils, or parent materials, in some areas will not support enough plant growth for erosion control due to excessive amount of some element or an unfavorable soil reaction. These include serpentine, high boron content, alkali, strongly acid, and probably other soils. A successful treatment of serpentine soils, and possibly for other problem soils, is to spread good soil over the problem areas during construction and to seed with adapted herbaceous species. Annual grasses will usually grow with a little good soil and the surface layer need be only a few inches deep. After establishment, the grasses may require maintenance applications of fertilizer to persist on these low-quality soils, particularly if the slopes are steep and erosive.

Agricultural minerals can be used to correct alkali and acid soils if the condition is not severe. The amounts of amendments can be roughly determined by soil scientists but the treatment may require leaching and soil mixing which may be impractical on steep slopes.

Another corrective treatment would be the seeding or planting of plants tolerant to the problem, such as seeding foxtail fescue on some strongly acid soils, or squirreltail on serpentine soils, or the planting of native shrubs tolerant to serpentine soils. Neither foxtail fescue or squirreltail is available commercially, though foxtail fescue is in seed increase at the Lockeford Plant Materials Center. At present, however, the planting of shrubs or trees on problem soils is not recommended unless specific examples of success are known. Generally, little is known about the treatment of these problem soils on highway slopes. Investigations need to be made and studies conducted in this field.

Suggested highway evaluation trials.

Limited amounts of seed of promising grass and legume species are available at the Lockeford Plant Materials Center for testing on disturbed areas along California highways. Seeds would be on a trial basis. CALTRANS would furnish the sites, treat the slopes as necessary, and apply the seed, fertilizer, and mulch. The U.S.D.A. Soil Conservation Service would supply the seed. These trials would be evaluated by personnel of CALTRANS and the Soil Conservation Service.

These results would be interpreted cooperatively. Six herbaceous species may soon be available for trials: 1) foxtail fescue for very acid, shallow, or gravelly soils (but not where there is human or dog travel because of the sharp-pointed seeds), 2) red brome for drier areas or shallow soils on dry sites (but not when there is human or dog travel), 3) big quakinggrass in coastal areas for use with wildflowers, 4) annual bluegrass for median or fire strips in areas of 16 inches or more rainfall, 5) bur clover in areas of 16 inches or less rainfall and in place of other legumes, and 6) the California poppy (one having a light yellow compact flower, collected at Truckee) for trials at higher elevations.

MAJOR LAND RESOURCE AREAS
CALIFORNIA

SEPTEMBER 1963

40 0 40 80 120

SCALE IN MILES

USDA SCS PORTLAND OREG 1963 M-4029

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MLRA-4. NORTHERN CALIFORNIA REDWOOD BELT

Major Land Resource Area 4 is found along the Pacific Coast from Jenner, Sonoma County, to the Oregon state line, in Santa Cruz County, and a small area in Monterey County. This is a humid area characterized by high average annual rainfall ranging from 32 to 80 inches, and as a result, 68% of the land is forested. The dominant species are coastal redwood and Douglas fir. General elevations range from sea level to 2500 feet. The maximum extension inland is about 25 miles. Land forms vary from sand dunes to mountains. Because of favorable rainfall and other climatic factors, reproduction and revegetation take place readily. The soils are usually acid, limiting growth of many plants. Severe erosion occurs on disturbed upland soils.

Perennial mixture	Seeding rate pounds/acre	Minimum 1/ P and G	
Agropyron trichophorum* 'Luna' (Luna pubescent wheatgrass)	20	95	80
Dactylis glomerata 'Palestine' (Palestine orchardgrass)	15	85	80
Lotus corniculatus (broadleaf trefoil)+	5	98	80
Optional			
Trifolium incarnatum (crimson clover)+	5	98	85
Eschscholzia californica (California poppy)	3	90	85
Bromus mollis 'Blando' (Blando brome)	5	95	85
Annual mixture			
Lolium multiflorum (annual ryegrass)	20	99	85
Bromus mollis 'Blando' (Blando brome)	10	95	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	10	99	85
Rapid cover			
Hordeum vulgare (barley)	180	97	80
Bromus mollis 'Blando' (Blando brome)	20	95	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	20	99	85
or			
Lolium multiflorum (annual myegrass)	60	99	85
Bromus mollis 'Blando' (Blando brome)	20	95	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	20	99	85

* Luna has not been adequately tested in MLRA-4.
\+ Inoculate all legume seed.
Fertilizer recommendations: Ammonium phosphate sulfate 16-20-0 preferred at 400 pounds/acre; or ammonium sulfate 21-0-0 at 300 pounds/acre.
1/ Percent minimum purity and germination.

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MLRA-14. CENTRAL CALIFORNIA COASTAL VALLEYS
MLRA-15. CENTRAL CALIFORNIA COAST RANGE
MLRA-16. CALIFORNIA DELTA
MLRA-17. SACRAMENTO AND SAN JOAQUIN VALLEYS
MLRA-18. SIERRA NEVADA FOOTHILLS

Major Land Resource Areas 14, 15, 16, 17, and 18 cover a wide area with a mild Mediterranean-type climate in central and northern California including the lands fronting along the Pacific Ocean, the coastal, inland and Sierra Nevada foothills up to 5000 feet in the south, the coastal and inland mountainous areas, valleys subjected to sea breezes, and the hotter and sometimes drier Sacramento and San Joaquin Valleys. Rainfall is highly variable, ranging from 5 inches near Bakersfield to about 35 inches near timbered areas. Mediterranean annual grasses, forbs and legumes dominate grassy areas. These areas are combined because several of the better species for erosion control can be commonly used throughout.

Perennial mixture. Mean annual precipitation 16" plus (fill slopes or cut slopes with deep soils)	Seeding rate pounds/acre	Minimum 1/ P and G	
Agropyron trichophorum 'Luna' (Luna pubescent wheatgrass)	25	95	80
Dactylis glomerata 'Palestine' (Palestine orchardgrass)	10	85	80
Trifolium hirtum (rose clover)+	5	99	85
Optional			
Trifolium incarnatium (crimson clover)+	5	98	85
Eschscholzia californica (California poppy)	3	90	85
Bromus mollis 'Blando' (Blando brome)	5	95	85

Annual mixture. Mean annual precipitation 12" plus

1. Near coast

Bromus mollis 'Blando' (Blando brome)	25	95	85
Lolium multiflorum (annual ryegrass)	10	99	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	10	99	85
or			
Bromus mollis 'Blando' (Blando brome)	30	95	85
Trifolium hirtum (rose clover)+	10	99	85
Optional			
Trifolium incarnatum (crimson clover)+	5	98	85
Eschscholzia californica (California poppy)	3	90	85

2. Inland

Bromus mollis 'Blando' (Blando brome)	25	95	85
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	10	97	85

Annual mixture (Continued)	Seeding rate pounds/acre	Minimum 1/ P and G	
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	10	99	85
or			
Bromus mollis 'Blando' (Blando brome)	30	95	85
Trifolium hirtum (rose clover)+	10	99	85
Optional			
Trifolium incarnatum (crimson clover)+	5	98	85
Eschscholzia californica (California poppy)	3	90	85
Annual mixture. Mean annual precipitation 6-12"			
Bromus mollis 'Blando' (Blando brome)	30	95	85
Trifolium hirtum (rose clover)+	10	99	85
Rapid cover. Mean annual precipitation 12" plus			
Hordeum vulgare 'Briggs' (Briggs barley)	180	97	80
Bromus mollis 'Blando' (Blando brome)	20	95	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	20	99	85
or			
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	60	97	85
Bromus mollis 'Blando' (Blando brome)	20	95	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	20	99	85
Rapid cover. Mean annual precipitation 10-12"			
Hordeum vulgare 'Briggs' (Briggs barley)	180	97	80
Bromus mollis 'Blando' (Blando brome)	20	95	85
Trifolium hirtum (rose clover)+	10	99	85
or			
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	60	97	85
Bromus mollis 'Blando' (Blando brome)	20	95	85
Trifolium hirtum (rose clover)+	10	99	85

+ Inoculate all legume seed.
Fertilizer recommendations: Ammonium phosphate sulfate preferred

	Ammonium phosphate sulfate 16-20-0 (pounds/acre)	Ammonium sulfate 21-0-0 (pounds/acre)
Mean annual rainfall 16" plus	400	300
Mean annual rainfall 10-16"	300	230
Mean annual rainfall 10" minus	200	150

1/ Percent minimum purity and germination.

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MLRA-19. SOUTHERN CALIFORNIA COASTAL PLAIN

This area includes plains, low hills, valleys, and low mountains along the coast from around Santa Barbara south to Mexico. From Los Angeles, the area extends inland to San Bernadino and Hemet surrounding the Santa Ana Mountains, which are in MLRA-20. Rainfall varies from 10 to 20 inches. This area is known as the citrus belt, having mild winters and with fog along the coast. Elevations range from sea level to 2000 feet. Sandy soils in the vicinity of Cucamonga are subject to wind erosion. The erosion hazard is low on alluvial soils but high on steep upland slopes.

Perennial mixture. Coastal influence (deep, light sandy soils*)	Seeding rate pounds/acre	Minimum 1/ P and G	
Ehrharta calycina 'Mission' (Mission veldtgrass)	20	64	75
Agropyron trichophorum** 'Luna' (Luna pubescent wheatgrass)	10	95	80
Trifolium hirtum (rose clover)+	10	99	85
Optional			
Eschscholzia californica (California poppy)	3	90	85
Bromus mollis 'Blando' (Blando brome)	5	95	85
Perennial mixture. Mean annual precipitation 16" plus (fill slopes or cut slopes with deep soils)			
Agropyron trichophorum** 'Luna' (Luna pubescent wheatgrass)	30	95	80
Dactylis glomerata** 'Palestine' (Palestine orchardgrass)	5	85	80
Trifolium hirtum (rose clover)+	5	99	85
Optional			
Eschscholzia californica (California poppy)	3	90	85
Bromus mollis 'Blando' (Blando brome)	5	95	85
Annual mixture. Mean annual precipitation 12" plus			
Bromus mollis 'Blando' (Blando brome)	25	95	85
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	10	97	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	10	99	85
Annual mixture. Mean annual precipitation 10-12"			
Bromus mollis 'Blando' (Blando brome)	30	95	85
Trifolium hirtum (rose clover)+	10	99	85
Optional			
Eschscholzia californica (California poppy)	3	90	85

Rapid cover. Mean annual precipitation 12" plus	Seeding rate pounds/acre	Minimum 1/ P and G	
Hordeum vulgare 'Briggs' (Briggs barley)	180	97	80
Bromus mollis 'Blando' (Blando brome)	20	95	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	20	99	85
Rapid cover. Mean annual precipitation 10-12"			
Hordeum vulgare 'Briggs' (Briggs barley)	180	97	80
Bromus mollis 'Blando' (Blando brome)	20	95	85
Trifolium hirtum (rose clover)+	10	99	85

* Soils highly erosive, slopes should probably be straw mulched.
** 'Luna' and 'Palestine' have not been adequately tested in MLRA-19.
+ Inoculate all legume seed.
Fertilizer recommendations: Ammonium phosphate sulfate preferred

	Ammonium phosphate sulfate 16-20-0 (pounds/acre)	Ammonium sulfate 21-0-0 (pounds/acre)
Mean annual rainfall 16" plus	400	300
Mean annual rainfall 10-16"	300	230
Mean annual rainfall 10" minus	200	150

1/ Percent minimum purity and germination.

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MLRA-20. SOUTHERN CALIFORNIA MOUNTAINS

This area extends from the southern part of San Luis Obispo County through several mountain ranges to the Mexican border. The Santa Ana Mountains in Orange County are also included. Fifty-five percent of the area is made up of vast brush-fields with steep slopes, 22% is grassy, 10% is oak-woodland, and at higher elevations 3% is timbered. The elevations range from about 2000 feet to nearly 12,000 feet. Precipitation is generally 16-30 inches, with as much as 40 inches in small forested areas at higher elevations.

Perennial mixture. Mean annual precipitation 16" plus	Seeding rate pounds/acre	Minimum 1/ P and G	
1. Above 3500' elevation--coast side of mountains			
Agropyron trichophorum 'Luna' (Luna pubescent wheatgrass)	20	95	80
Agropyron intermedium 'Greenar' (Greenar intermediate wheatgrass)	10	95	85
Poa ampla 'Sherman' (Sherman big bluegrass)	10	90	70
Bromus mollis 'Blando' (Blando brome)	5	95	85
2. Above 3000' elevation--desert side of mountains			
Agropyron trichophorum 'Luna' (Luna pubescent wheatgrass)	20	95	80
Agropyron cristatum 'Fairway' (Fairway crested wheatgrass)	10	95	80
Poa ampla 'Sherman' (Sherman big bluegrass)	10	90	70
3. Below 3500' elevation--coast side of mountains			
Agropyron trichophorum 'Luna' (Luna pubescent wheatgrass)	20	95	80
Dactylis glomerata* 'Palestine' (Palestine orchardgrass)	10	85	80
Oryzopsis miliacea (smilo)	10	99	70
Bromus mollis 'Blando' (Blando brome)	5	95	85
Annual mixture. Below 3500' elevation			
Bromus mollis 'Blando' (Blando brome)	25	95	85
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	10	97	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	10	99	85
or			
Bromus mollis 'Blando' (Blando brome)	30	95	85
Trifolium hirtum (rose clover)+	10	99	85
Eschscholzia californica (California poppy)	3	90	85

Rapid cover	Seeding rate pounds/acre		Minimum 1/ P and G
1. Above 3500' elevation			
Secale cereale (cereal rye)	120	97	80
2. Below 3500' elevation			
Secale cereale (cereal rye)	120	97	80
or			
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	60	97	85
Bromus mollis 'Blando' (Blando brome)	20	95	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	20	99	85

* 'Palestine' has not been adequately tested in MLRA-20.
\+ Inoculate all legume seed.
Fertilizer recommendations: Ammonium phosphate sulfate preferred

	Ammonium phosphate sulfate 16-20-0 (pounds/acre)	Ammonium sulfate 21-0-0 (pounds/acre)
Mean annual rainfall 16" plus	400	300
Mean annual rainfall 10-16"	300	230
Mean annual rainfall 10" minus	200	150

1/ Percent minimum purity and germination.

Revised 4/10/75

MLRA-21. KLAMATH AND SHASTA VALLEYS AND BASINS

This area is in the north central and northeastern part of California. The area is characterized by upland lava mesas interspersed with mountain valleys and lake basins. Elevations range from about 2500 to 4500 feet. Precipitation ranges from about 10 to 33 inches. Generally, it is too meager to support stands of forest trees. The dominant woody vegetation is juniper, sagebrush, rabbitbrush, bitterbrush, and mountain mahogany with scattered Jeffrey pine trees. The drought-tolerant wheatgrasses such as crested and Luna pubescent are well adapted.

Perennial mixture	Seeding rate pounds/acre	Minimum 1/ P and G	
Agropyron trichophorum 'Luna' (Luna pubescent wheatgrass)	20	95	80
Agropyron cristatum 'Fairway' (Fairway crested wheatgrass)	10	95	80
Poa ampla 'Sherman' (Sherman big bluegrass)	10	90	70
Optional			
Bromus mollis* 'Blando' (Blando brome)	5	95	85
Rapid cover			
Secale cereale** (cereal rye)	120	97	80

* Tests incomplete. Did well at Alturas with straw mulch.
** Cereal rye is weedy and should not be used where it may endanger croplands.
Fertilizer recommendations: Ammonium phosphate sulfate preferred

	Ammonium phosphate sulfate 16-20-0 (pounds/acre)	Ammonium sulfate 21-0-0 (pounds/acre)
Mean annual rainfall 16" plus	400	300
Mean annual rainfall 10-16"	300	230
Mean annual rainfall 10" minus	200	150

1/ Percent minimum purity and germination.

Revised 4/10/75

MLRA-5. SISKIYOU-TRINITY AREA
MLRA-22. SIERRA NEVADA MOUNTAINS

These areas are in the mountains and mountain valleys at general elevations of 1300 to over 8000 feet. Precipitation ranges from 30 to 84 inches in MLRA-5 and from 26 to over 100 inches in MLRA-22. Generally, the winters are cold with snow but at lower elevations the cold climate merges with the Mediterranean climate and wide belts exist where high and low elevation species intermingle. Most of the mountain slopes are forested.

Mediterranean climate	Seeding rate pounds/acre	Minimum 1/ P	and G
Perennial mixture			
Agropyron trichophorum 'Luna' (Luna pubescent wheatgrass)	25	95	80
Dactylis glomerata 'Palestine' (Palestine orchardgrass)	10	85	80
Trifolium hirtum (rose clover)+	5	99	85
Optional			
Trifolium incarnatum (crimson clover)+	5	98	85
Eschscholzia californica (California poppy)	3	90	85
Bromus mollis 'Blando' (Blando brome)	10	95	85
Annual mixture			
Bromus mollis 'Blando' (Blando brome)	25	95	85
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	10	97	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	10	99	85
or			
Bromus mollis 'Blando' (Blando brome)	30	95	85
Trifolium hirtum (rose clover)+	10	99	85
Optional			
Trifolium incarnatum (crimson clover)+	55	98	85
Eschscholzia californica (California poppy)	3	90	85
Rapid cover			
Hordeum vulgare 'Briggs' (Briggs barley)	180	97	80
Bromus mollis 'Blando' (Blando brome)	20	95	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	20	99	85
or			
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	40	97	5
Bromus mollis 'Blando' (Blando brome)	20	95	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	20	99	85

(continued)

Lower Ponderosa pine belt	Seeding rate pounds/acre	Minimum 1/ P and G	
Perennial mixture			
Agropyron trichophorum 'Luna' (Luna pubescent wheatgrass)	30	95	80
Dactylis glomerata 'Palestine' (Palestine orchardgrass)	10	85	80
Optional			
Trifolium hirtum (rose clover)+	5	99	85
Eschscholzia californica (California poppy)	3	90	85
Bromus mollis 'Blando' (Blando brome)	10	95	85
Annual mixture			
Bromus mollis 'Blando' (Blando brome)	25	95	85
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	10	97	85
Vicia dasycarpa 'Lana' (Lana woolypod vetch)+	10	99	85
Rapid cover			
Secale cereal (cereal rye)	90	97	80
Lolium rigidum 'Wimmera 62' (Wimmera 62 ryegrass)	80	97	85
Above lower Ponderosa pine zone			
Perennial mixture			
1. Siskiyou-Trinity and west side of Sierra Nevada Mountains			
Agropyron trichophorum 'Luna' (Luna pubescent wheatgrass)	10	95	80
Agropyron intermedium 'Tegmar' or 'Oahe' (Tegmar or Oahe intermediate wheatgrass)	10	95	85
Poa ampla 'Sherman' (Sherman big bluegrass)	5	90	70
Dactylis glomerata 'Latar' or 'Potomac' (Latar or Potomac orchardgrass)	5	90	85
Bromus inermis 'Manchar' (Manchar smooth brome)	5	98	85
Astragulus cicer* (cicer milkvetch)+	5	99	85
or for a shorter stand but not as good a cover			
Agropyron riparium 'Sodar' (Sodar streambank wheatgrass)	15	90	80
Festuca ovina duriuscula 'Durar' (Durar hard fescue)	10	95	85
Dactylis glomerata 'Pomar' (Pomar orchardgrass)	10	90	85
Astragulus cicer* (cicer milkvetch)+	5	99	85

(Continued)

Perennial mixture (Continued)	Seeding rate pounds/acre	Minimum 1/ P and G	
2. East side of Sierra on drier sites			
Agropyron trichophorum 'Luna' (Luna pubescent wheatgrass)	20	95	80
Agropyron cristatum 'Fairway' (Fairway crested wheatgrass)	10	95	80
Poa ampla 'Sherman' (Sherman big bluegrass)	10	90	70

* Use scarified seed.
+ Inoculate all legume seed.
Fertilizer recommendations: Ammonium phosphate sulfate 16-20-0 preferred at 400 pounds/acre; or ammonium sulfate 21-0-0 at 300 pounds/acre.
Tahoe Basin use 250 pounds/acre ammonium phosphate sulfate 16-20-0 or 200 pounds/acre ammonium sulfate 21-0-0.

Revised 4/10/75

MLRA-29. SOUTHERN NEVADA BASIN AND RANGE

This area includes most of Inyo County west of Bishop excluding Death Valley and extends into Mono and San Bernadino Counties. Elevations range from 2000 to 5000 feet in valleys to over 13,000 feet in mountainous areas. Mean annual precipitation ranges from 5 inches at lower elevations to 15 inches in the mountains.

Perennial mixture. Mean annual precipitation 10" minus	Seeding rate pounds/acre	Minimum 1/ P and G	
Oryzopsis hymenoides* (Indian ricegrass)	20	90	11-40
Agropyron trichophorum* 'Luna pubescent wheatgrass)	20	95	80
Agropyron cristatum* 'Fairway' (Fairway crested wheatgrass)	10	95	80
Bromus mollis* 'Blando' (Blando brome)	10	95	85
Rapid cover. Mean annual precipitation 10" plus			
Secale cereale (cereal rye)	120	97	80
Shrubs**			
Atriplex confertifolia (shadscale)	5		
Atriplex canescens (fourwing saltbush)	5		
Eriogonum fasciculatum polifolium (California buckwheat)	5		

* Not adequately tested in MLRA-29.
** Best to collect seed from vicinity of use.
Inoculate all legume seed.
Fertilizer recommendations: Ammonium phosphate sulfate preferred

	Ammonium phosphate sulfate 16-20-0 (pounds/acre)	Ammonium sulfate 21-0-0 (pounds/acre)
Mean annual rainfall 10-15"	300	230
Mean annual rainfall 10" minus	200	150

1/ Percent minimum purity and germination.

Note: Because of low and erratic precipitation and dry air, plant establishment and growth are difficult. To enhance establishment of grasses and native shrubs stockpile the top 2-4 inches of soil from construction areas and respread on disturbed soils. Run over with a tracklayer tractor or a sheepsfoot roller, or if strawed, with a straw puncher to make a good bond between the topsoil and the underlying material. Punch straw into soil with a straw puncher.

Revised 4/10/75

MLRA-30. SONORAN BASIN AND RANGE

This desert area includes most of southern Nevada, southwestern Arizona, and southeastern California from Death Valley to the Mexican Border. Elevations range from 282 feet below sea level to over 5000 feet above sea level. Rainfall usually averages less than 5 inches annually, often occurring in thundershowers. Several years may elapse before enough rainfall occurs in one or a series of years to establish plants. The area is very hot in summer, with below freezing temperatures on winter nights. No information has been found of previous seedings in this area, mainly because the area is a desert and considered impractical to revegetate.

Perennial mixture	Seeding rate pounds/acre	Minimum 1/ P and G	
Oryzopsis hymenoides* (Indian ricegrass)	20	90	11-40
Bromus mollis* 'Blando' (Blando brome)	5	95	85

* Not adequately tested in MLRA-30.
1/ Minimum purity and germination.
Fertilizer recommendations: Ammonium phosphate sulfate 16-20-0 at 200 pounds per acre; if not available, 150 pounds of ammonium sulfate 21-0-0.
Note: Very little is known about establishing vegetation in the desert without irrigation. Low and erratic rainfall and low humidity make plant establishment and growth extremely difficult. Several suggestions are listed below which would reduce erosion or improve the chances of plant establishment.

1. Spread topsoil on areas with a high erosion hazard in order to enhance plant establishment and also to provide seed of native plants found in or along the rights-of-way. Run over the soil with a tracklayer tractor or sheepsfoot roller to get a good bond with the underlying soil. This soil can be obtained from the top 2-4 inches of soil in the construction area and stockpiled for later use. More seed could be obtained where existing vegetation is plentiful.

2. Mulch erodible areas with a tough straw such as lovegrass or tall fescue. (Call Lockeford PMC.) The fiberglass roving-asphalt emulsion mulch could work as well or better than straw.

3. Leave slopes rough, especially cut slopes, so seed will have a place to lodge and germinate.

4. Make narrow borrow pits at right angles to prevailing winds.

5. Take care during construction not to disturb any more area than necessary.

6. Search ahead of time for areas that are erosion risks and require special protection. Many areas may not need treatment because of the rocky nature of the slopes.

7. In local areas of higher rainfall, use seeding recommendations for MLRA-29.

Table 29. Substitutes, growth, seed characteristics, and approximate cost of seed for species listed for use in the Major Land Resource Areas in the Herbaceous Seeding Guide for California. (Revised 4/10/75)

Common name	Scientific name	Variety	1/ Substitute	2/ Growth form	2/ Height (feet)	3/ Color (green)	4/ Days for germination	Purity of seed %	Germination %	Seeds per pound (1000)	Viable seeds per 5/ F2/1 lb/ac	6/ Cost per pound
GRASSES												
bluegrass, annual	Poa annua	-	None	A	0.5	Gr	7-21	95	97	1196	25	ASK
bluegrass, big blue	Poa ampla	Sherman	None	B	2-3	BlGr		90	70	917	13.2	0.85
brome, red*	Bromus rubens	-	Blando brome	A	1-2	LtGr		90	80	259	2.9	Seed increase Lockeford PMC
brome, smooth	Bromus inermis	Manchar	Lincoln smooth brome	R	2-3	Gr	6-14	95	85	125	2.4	0.90
brome, soft chess	Bromus mollis	Blando	Wimmera 62 ryegrass or annual ryegrass	A	1.5-2.5	GyGr	7-14	95	85	265	4.9	1.10
Canarygrass, reed	Phalaris arundinacea	-	None	R	3-6	GyGr	5-21	99	70	506	8.0	0.90
Fescue, foxtail*	Festuca megalura	-	Blando brome	A	1-2.3	Gr	7-14	95	85	800	19.9	Seed increase Lockeford PMC
Fescue, hard	Festuca ovina duriuscula	Durar	None	B	1-2	Cr	7-28	95	85	565	10.5	1.65
orchardgrass	Dactylis glomerata	Latar	Potomac orchardgrass	B	2-4	Gr	7-21	90	85	540	9.6	0.73
orchardgrass	Dactylis glomerata	Pomar	None	B	1.5-2	Gr	7-21	90	85	540	9.6	0.75
orchardgrass	Dactylis glomerata	Palestine	Luna pubescent wheatgrass	B	2-4	Gr	7-21	85	80	540	8.4	ASK
quakinggrass	Briza maxima	-	Blando brome	A	1-3	Gr		90	75	**300	4.6	Seed increase Lockeford PMC

Table 29. Continued

Common name	Scientific name	Variety	1/ Substitute	2/ Growth form	Height (feet)	3/ Color (green)	4/ Days for germination	Purity of seed %	Germination %	Seeds per pound (1000)	Viable seeds per 5/ F2/1 lb/ac	6/ Cost per pound
ricegrass, Indian	Oryzopsis hymenoides	-	Possibly Fairway crested wheatgrass	B	2-3	LtGr	7-42	90	11-40	235	0.59-2.4	ASK
ryegrass, annual	Lolium multiflorum	-	Blando brome, Wimmera 62 ryegrass	A	1.5-3	Gr	5-14	99	85	217	4.1	0.30
ryegrass, Wimmera	Lolium rigidum	Wimmera 62	Blando brome, annual ryegrass	A	1.5-3	Gr	5-14	97	85	185	3.5	0.39
smilo	Oryzopsis miliacea	-	None	B	2-4	Gr	7-42	99	70	1900	30.1	ASK
veltgrass	Ehrharta calycina	Mission	Luna pubescent wheatgrass or Palestine orchardgrass	B	2-3	Gr	7-28	64?	75?	300	3.3	ASK
wheatgrass, crested	Agropyron cristatum	Fairway	Nordan crested wheatgrass or Luna pubescent wheatgrass	B	2-3	Gr	5-14	95	80	200	3.5	0.55
wheatgrass, intermediate	Agropyron intermedium	Greenar	Tegmar intermediate wheatgrass, Oahe intermediate wheatgrass	R	3-4	BlGr	5-28	95	85	100	1.9	0.70
wheatgrass, intermediate	Agropyron intermedium	Tegmar	Luna pubescent wheatgrass, Oahe intermediate wheatgrass	R	3-3.8	Gr	5-28	95	85	100	1.9	0.70
wheatgrass, pubescent	Agropyron trichophorum	Luna	Tegmar intermediate wheatgrass, Oahe intermediate wheatgrass	R	3-4	BlGr	5-28	95	80	91	1.6	0.65

Table 29. Continued

Common name	Scientific name	Variety	1/ Substitute	2/ Growth form	Height (feet)	3/ Color (green)	4/ Days for germination	Purity of seed %	Germination %	Seeds per pound (1000)	5/ Viable seeds per F2/1 lb/ac	6/ Cost per pound
wheatgrass, streambank	Agropyron riparium	Sodar	Possibly Barton western wheatgrass	R	1-2	BlGr		90	80	170	2.8	2.25
wheatgrass, western	Agropyron smithii	Barton	Luna pubescent wheatgrass	R	1-2	BlGr	7-28	80	60	110	1.2	1.10
LEGUMES												
clover, bur	Medicago hispida	-	None in low rainfall	A	0.5-1	Gr	4-14	98	85	212	4.1	ASK
clover, crimson	Trifolium incarnatum	-	Rose clover	A	2-3	Gr	4-17	98	85	140	2.7	0.90
clover, rose	Trifolium hirtum	Wilton Hykon	None	A	0.5-1	GyGr	4-10	99	85	116	2.2	1.20
clover, subterranean	Trifolium subterraneum	Mt. Barker	None	A	0.5-1	Gr	4-14	98	80	75	13.5	1.25
lupine	Lupinus vallicola	-	Purple annual lupine	A	0.5-1	Gr	5+					ASK
lupine, purple annual	Lupinus succulentus	-	Lupinus vallicola	A	1-2	Gr	5+	99	95	18	0.35	10.00
milkvetch, cicer	Astragulus cicer	Cicar	Lutana cicer milkvetch	R	2-4	Gr	10+	99	85	145	2.8	2.75
Trefoil, broadleaf	Lotus corniculatus	Cascade	Other broadleaf strains, narrowleaf	B	0.5-1.5	Gr	5-10	99	85	470	9.1	2.25
Trefoil, narrowleaf	Lotus tenuis	-	Cascade or commercial broadleaf trefoil	B	0.5	Gr	5-10	98	80	485	8.7	3.25
vetch, woolypod	Vicia dasycarpa	Lana	Rose clover	A	2-4	Gr	5-24	99	85	11	0.20	0.35

Table 29. Continued

Common name	Scientific name	Variety	1/ Substitute	2/ Growth form	Height (feet)	3/ Color (green)	4/ Days for germination	Purity of seed %	Germination %	Seeds per pound (1000)	Viable seeds per F2/1 lb/ad 5/	6/ Cost per pound
CEREAL GRAIN												
barley	Hordeum vulgare	Briggs	CM 67, Numar, Blue mariot	A	2-3	Gr	4-7	97	80	13.6	0.24	0.15
rye, cereal	Secale cereale	-	Barley at lower	A	3-4	Gr	4-7	97	80	18.0	0.39	0.19
FORB												
poppy, California	Eschscholzia californica	-	None	A-B	1-2	Gr	7+	90	85	302	5.6	10.00

* Seed has sharp awn which can get into dogs' ears, eyes, and feet; plants are exotic naturalized species that are widespread in nature.
** Partially deglumed in hammermill.
1/ "Substitutions" may be with strains, species, or genera. "None" indicates there is no suitable substitute, replace with another type or if in mixture use one of major species.
2/ Growth form: A = annual B = perennial, no rhizomes R = perennial with rhizomes
3/ Green color: BlGr = bluegreen GyGr = graygreen LtGr = light green
4/ Days for germination: the first figure is the number of days to "first count" in germination trials (Rules and Regulations under the Federal Seed Act). In practice, germination has been more rapid when the weather has been warm and the soil moist. For example, Blando brome germinated in 3 days instead of 7.
5/ Viable seeds per square foot at a one pound per acre seeding rate =

$$\frac{\text{seeds per pound} \times \frac{\text{purity \%} \times \text{germination \%}}{100}}{43{,}560 \text{ square feet}}$$

6/ Estimated cost in fall of 1974.

APPENDIX C

A List of Native Shrubs and Trees for Revegetation and Erosion Control by Major Land Resource Areas

A LIST OF NATIVE SHRUBS AND TREES FOR REVEGETATION AND EROSION CONTROL BY MAJOR LAND RESOURCE AREAS

Developed for

THE CALIFORNIA DEPARTMENT OF TRANSPORTATION
OFFICE OF LANDSCAPE AND ARCHITECTURAL DESIGN

as part of the

PLANT MATERIALS STUDY

by

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

Lockeford, California

George Edmunson

Project Leader

Revised 5/2/75

FOREWORD

This list of native shrubs and trees has been compiled as a guide for the landscape designer who uses native species for roadside plantings or seedings. The plants are mainly for revegetation, although they also provide erosion control. They are listed by botanical names under the Major Land Resource Areas. Common name equivalents can be found in Appendix D.

No attempt is made to describe the species or their possible uses aside from revegetation. They are listed simply to give the designer a broad overlook of the native shrubs and trees he might expect to find in an area proposed for construction. This list is not to take the place of an onsite review of the native vegetation.

Several sources were used in developing the list. Although the species mentioned in each Major Resource Area Guide served as a basis, "A California Flora" by Munz and Keck was heavily relied upon, along with the "Manual of Flowering Plants in California" by Jepson, and "An Illustrated Manual of California Shrubs" by McMinn. Other publications were used such as "California Range Brushlands and Browse Plants," by Sampson and Jespersen. Common names were obtained from "Seeds of Woody Plants in the United States," by the U.S.D.A. Forest Service whenever applicable.

MAJOR LAND RESOURCE AREAS
CALIFORNIA

SEPTEMBER 1963

40 0 40 80 120

SCALE IN MILES

MAJOR LAND RESOURCE AREAS

4	Californio Coastol Redwood Belt
5	Siskiyou-Trinity Areo
14	Central California Coastal Valleys
15	Central Californio Coast Ronge
16	California Delto
17	Sacromento and Son Jooquin Volleys
18	Sierra Nevodo Foothills
19	Southern Californio Coostal Ploin
20	Southern Californio Mountains
21	Klamoth and Shasta Valleys and Bosins
22	Sierra Nevodo Ronge
23	Molheur High Plateou
26	Carson Bosin and Mountains
29	Southern Nevoda Basin and Ronge
30	Sonoron Basin ond Ronge
31	Imperial Valley

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MLRA-4. NORTHERN CALIFORNIA REDWOOD BELT.

Major Land Resource Area 4 is found along the Pacific Coast from Jenner, Sonoma County to the Oregon state line, in Santa Cruz County, and a small area in Monterey County. This is a humid area and is characterized by high average annual rainfall ranging from 32 to 80 inches, and as a result 68% of the land is forested. The dominant species are Coast redwood and Douglas fir. General elevations range from sea level to 2500 feet. The maximum extension inland is about 25 miles. Land forms vary from sand dunes to mountains. Because of favorable rainfall and other climatic factors, reproduction and revegetation take place readily. The soils are usually acid, limiting growth of many plants. Severe erosion occurs on disturbed upland soils.

Native shrubs

Acer circinatum
Arctostaphylos nummularia
Artostaphylos pumila
Arctostaphylos uva-ursi coactilis
Baccharis pilularis
Baccaris pilularis var. consanguinea
Ceanothus foliosus
Ceanothus gloriosus
Ceanothus griseus horizontalis
Ceanothus incanus
Ceanothus papillosus
Ceanothus sorediatus
Ceanothus thyrsiflorus
Ceanothus thyrsiflorus repens
Ceanothus velutinus laevigatus
Gaultheria shallon
Holodiscus discolor
Mimulus aurantiacus
Myrica californica
Rhamnus purshiana
Rhododendron macrophyllum
Rhododendron occidentale

Native trees

Abies grandis
Arbutus menziesii
Castanopsis chrysophylla
Chamaecyparis lawsoniana
Cupressus pygmaea
Lithocarpus densiflora
Picea sitchensis
Pinus contorta
Pinus muricata
Pseudotsuga menziesii
Sequoia sempervirens
Thuja plicata
Tsuga heterophylla
Umbellularia californica

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MLRA-5. SISKIYOU-TRINITY AREA.

The Siskiyou-Trinity Area extends southward from Oregon into the northern tip of Lake County and eastward from the central area to the crest of the Marble Mountains and the Trinity Mountains. General elevations range from 3000 to 4000 but come as low as 1300 feet into the Mediterranean climatic zone. Rainfall is high, ranging from 30 to 85 inches. Much of the area is forested.

Native shrubs

Arctostaphylos manzanita*
Arctostaphylos nevadensis
Arctostaphylos patula
Arctostaphylos viscida*
Ceanothus cordulatus
Ceanothus integerrimus
Ceanothus papillosus*
Ceanothus parryi*
Ceanothus prostratus
Ceanothus pumilus (Serpentine soil)
Ceanothus velutinus
Cornus nuttallii
Corylus cornuta californica
Mahonia aquifolium
Quercus dumosa*
Quercus sadleriana
Ribes nevadense
Ribes roezlii
Rubus parviflorus

Native trees

Abies concolor
Abies magnifica
Acer macrophyllum*
Arbutus menziesii
Castanopsis chrysophylla
Castanopsis sempervirens
Libocedrus decurrens
Lithocarpus densiflora
Pinus jeffreyi
Pinus lambertiana
Pinus monticola
Pinus murrayana
Pinus ponderosa
Populus tremuloides
Pseudotsuga menziesii
Quercus chrysolepis*
Quercus kelloggii*
Quercus garryana
Quercus wislizenii
Tsuga mertensiana

* Lower elevations

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MLRA-14. CENTRAL CALIFORNIA COASTAL VALLEYS
MLRA-15. CENTRAL CALIFORNIA COAST RANGE

Major Land Resource Areas 14 and 15 cover a wide area with a mild Mediterranean-type climate in Central California, including large valleys subject to sea breezes, the Central Coast Range west of the Great Central Valley, and lands fronting along the Pacific Ocean. The larger valleys include the Salinas, Santa Clara, and Napa Valleys. Rainfall is highly variable, ranging from 7 inches near Coalinga to about 40 inches near timber. Mediterranean annual species dominate grassy areas.

Native shrubs

Adenostema fasciculatum
Arctostaphylos glandulosa
Arctostaphylos glauca
Arctostaphylos manzanita
Arctostaphylos viscida
Artemesia californica
Atriplex lentiformis breweri
Baccharis pilularis var. consaguinea
Ceanothus cuneatus
Ceanothus impressus
Ceanothus papillosus
Ceanothus thrysiflorus
Cercis occidentalis
Cercocarpus betuloides
Dendromecon rigidii
Eriogonum fasciculatum
Fremontodendron californicum
Garrya flavens
Hetermeles arbutifolia
Holodiscus discolor
Mimulus aurantiacus
Pickeringia montana
Prunus ilicifolia
Quercus dumosa
Quercus wislizenii frutescens
Rhamnus californica
Rhamnus crocea
Salvia mellifera
Sambucus mexicana
Yucca whipplei

Native trees

Acer macrophyllum
Aesculus californica
Alnus rhombifolia
Arbutus menziesii
Cupressus sargentii
Lithocarpus densiflora
Pinus coulteri
Pinus ponderosa*
Pinus radiata
Pinus sabiniana
Quercus agrifolia
Quercus douglasii
Quercus kelloggii
Quercus lobata
Quercus wislizenii
Umbellularia californica

*Higher elevations in the mountains

Revised 5-2-75

MLRA-17. SACRAMENTO AND SAN JOAQUIN VALLEYS

Resource Area 17 includes the valley floor and gentle sloping hills. Rainfall varies from 6 inches near Bakersfield to 22 inches at Red Bluff. Although woodland areas occur in the Sacramento Valley and the northern part of the San Joaquin Valley, shrubs (except those found in alkaline areas) and trees are mostly limited to watercourses in the San Joaquin Valley.

Native shrubs

Allenrolfea occidentalis
(alkaline places)
Arctostaphylos viscida
Atriplex canescens
Atriplex lentiformis
Atriplex polycarpa
Ceanothus cuneatus
Cercic occidentalis
Eriodictyon californicum
Rhamnus californica
Ribes quercetorum
Salicornia subterminalis
(salt marshes + alkaline places)
Sambucus mexicana
Vitis californica

Native trees

Pinus sabiniana
Platanus racemosa
Populus fremontii
Populus trichocarpa
Quercus douglasii
Quercus lobata
Quercus wislizenii
Salix gooddingii
Salix laevigata
Salix lasiandra

Revised 5-2-75

MLRA-18. SIERRA NEVADA FOOTHILLS

The foothill area borders the Sacramento and San Joaquin Valleys along the footslopes of the Sierra Nevada and Cascade Mountain Ranges. The relief is hilly to rolling. Ninety-two percent of the area is made up of oak woodland, open grassy areas and chapparal. Digger pine is scattered throughout much of the area, and blue oak is the predominant tree. Elevations range from about 500 feet to 2500 feet in the north and up to 5000 feet in the south. Rainfall ranges from 35 inches in the north to 14 inches in the southern part. The landscapes along State Highway 49 from Mariposa to Placerville are typical of this area.

Native shrubs

Adenostema fasciculatum
Arctostaphylos manzanita
Arctostaphylos mariposa
Arctostaphylos viscida
Baccharis pilularis consanguinea
Ceanothus cuneatus
Cercis occidentalis
Eriodictyon californicum
Heteromeles arbutifolia
Mimulus aurantiacus
Quercus dumosa
Rhamnus californica
Rhamnus crocea
Ribes quercetorum
Salvia sonomensis
Yucca whipplei (north to Kings River)

Native trees

Aesculus californica
Arbutus menziesii
Pinus ponderosa
Pinus sabiniana
Quercus douglasii
Quercus chrysolepis
Quercus kelloggii
Quercus lobata
Quercus wislizenii
Umbellularia californica

Revised 5-2-75

MLRA-19. SOUTHERN CALIFORNIA COASTAL PLAIN

This area includes plains, low hills, valleys, and low mountains along the coast from around Santa Barbara south to Mexico. From Los Angeles, the area extends inland to San Bernardino and Hemet surrounding the Santa Ana Mountains, which are in MLRA-20. Rainfall varies from 10 to 20 inches. This area is known as the citrus belt, having mild winters and with fog along the coast. Elevations range from sea level to 2000 feet. Sandy soils in the vicinity of Cucamonga are subject to wind erosions. The erosion hazard is low on alluvial soils but high on steep upland slopes.

Native shrubs

Adenostema fasciculatum
Arctostaphylos glandulosa
Arctostaphylos glauca
Artemisia californica
Atriplex canescens
Atriplex lentiformis breweri
Baccharis pilularis var. consanguinea
Ceanothus oliganthus
Ceanothus spinosus
Chilopsis linearis (along water courses)
Encelia californica
Eriodictyon trichocalyx
Eriogonum fasciculatum
Eriophyllum confertiflorum
Fremontodendron californicum
Isomeris arborea
Mimulus aurantiacus
Mimulus longiflorus
Pickeringia montana
Prunus ilicifolia
Prunus lyonii (endemic to Catalina and other islands)
Quercus dumosa
Quercus wislizenii frutescens
Romneya coulteri
Rhus integrifolia
Rhus laurina
Rhus ovata
Rhus trilobata
Salvia apiana
Salvia leucophylla
Salvia mellifera
Trichostema lanatum
Yucca whipplei

Native trees

Juglans californica
Pinus sabiniana
Pinus torreyana (endemic to south coast)
Quercus agrifolia
Quercus chrysolepis
Quercus douglasii
Quercus engelmannii
Quercus lobata

Revised 5-2-75

MLRA-20. SOUTHERN CALIFORNIA MOUNTAINS

This area commences in the Sierra Madre and Santa Ynez Mountains in Santa Barbara County and continues along several mountain ranges through Southern California and into Mexico. The Santa Ana Mountains in Orange County are also included. Fifty-five percent of the area is made up of vast brush-fields with steep slopes, 22% is grassy, 10% is oak-woodland, and at higher elevations 3% is timbered. Elevations range from about 2000 feet to nearly 12,000 feet. Precipitation is generally 16-30 inches, with as much as 40 inches in small forested areas at higher elevations.

COASTAL SIDE

Native shrubs

Adenostema fasciculatum
Adenostema sparsifolium
Arctostaphylos glandulosa
Arctostaphylos glauca
Arctostaphylos parryana
Arctostaphylos parryana var. pinetorum
Arctostaphylos patula
Arctostaphylos pringlei drupacea
Ceanothus cordulatus
Ceanothus crassifolius
Ceanothus integerrimus var. puberulus
Ceanothus leucodermis
Cercocarpus betuloides
Eriodictyon trichocalyx
Garrya veatchii
Heteromeles arbutifolia
Holodiscus discolor
Pickeringia montana
Quercus dumosa
Yucca whipplei

Native trees

Abies concolor
Libocedrus decurrens
Pinus attenuata
Pinus coulteri
Pinus jeffreyi
Pinus lambertiana
Pinus ponderosa
Pseudotsuga macrocarpa
Quercus chrysolepis
Quercus kelloggii
Sambucus mexicana

DESERT SIDE

Native shrubs

Adenostema fasciculatum
Amelanchier utahensis
Arctostaphylos glauca
Ceanothus greggi
Cercocarpus ledifolius
Fremontodendron californicum
Hololodiscus microphyllus
Purshia glandulosa

Native trees

Juniperus californica
Juniperus occidentalis
Juniperus osteosperma
Pinus coulteri
Pinus edulis
Pinus monophylla
Pinus ponderosa
Pinus quadrifolia

(continued)

MLRA-20. SOUTHERN CALIFORNIA MOUNTAINS (Continued)

DESERT SIDE

Native shrubs	Native trees
Quercus dumosa	Quercus chrysolepis
Quercus turbinella	
Quercus turbinella var. californica	
Yucca schidigera	

Revised 5-2-75

MLRA-21. KLAMATH AND SHASTA VALLEYS AND BASINS

This area is in the north-central and northeastern part of California. The area is characterized by upland lava mesas interspersed with mountain valleys and lake basins. Elevations range from about 2500 to 4500 feet. Precipitation ranges from 10 to 33 inches. Generally it is too meager to support forest trees, and the dominant woody vegetation is juniper, sagebrush, rabbitbrush, bitterbrush, and mountain mahogany with scattered Jeffrey pine trees.

Native shrubs

Artemisia arbuscula
Artemisia cana
Artemisia tridentata
Atriplex canescens
Atriplex confertifolia
Cercocarpus betuloides macrourus
Cercocarpus ledifolius
Chrysothamnus nauseosus
Chrysothamnus viscidiflorus
Penstemon laetus
Penstemon speciosus
Prunus andersonii
Purshia tridentata
Symphoricarpus longiflorus

Native trees

Juniperus occidentalis
Pinus jeffreyi
Pinus monophylla
Populus tremuloides

MLRA-22. SIERRA NEVADA RANGE

These areas are in the mountains and mountain valleys at elevations from 1500 to over 8000 feet. Generally, the winters are cold with snow but at lower elevations the cold climate merges with the Mediterranean and wide belts exist where high- and low-elevation species intermingle. Most of the mountain slopes are forested.

MEDITERRANEAN CLIMATE

Native shrubs	Native trees
Adenostema fasciculatum	Abies concolor
Arctostaphylos manzanita	Arbutus menziesii
Arctostaphylos mariposa	Libocedrus decurrens
Arctostaphylos viscida	Pinus monticola
Ceanothus cuneatus	Pinus ponderosa
Ceanothus integerrimus	Pinus sabiniana
Ceanothus lemmonii	Pseudotsuga menziesii
Eriodictyon californicum	Quercus chrysolepis
Fremontodendron californicum	Quercus kelloggii
Heteromeles arbutifolia	
Mimulus aurantiacus	
Prunus virginiana demissa	
Quercus dumosa	
Rhamnus californica tomentella	
Ribes quercetorum	

At higher elevations include species of Lower Ponderosa Pine Forest; at lower elevations include species of the Sierra Nevada Foothills (MLRA 18).

LOWER PONDEROSA PINE FOREST

Native shrubs	Native trees
Amelanchier pallida	Abies concolor
Arctostaphylos mariposa	Libocedrus decurrens
Arctostaphylos mewukka	Pinus lambertiana
Arctostaphylos patula	Pinus ponderosa
Arctostaphylos viscida	Pseudotsuga menziesii
Ceanothus integerrimus	Quercus chrysolepis
Ceanothus prostratus	Quercus kelloggii
Ceanothus velutinus	Sequoiadendron giganteum
Chamaebatia foliolosa	(limited range)
Cornus nuttallii	
Cornus stolonifera	
Corylus rostrata var. californica	
Fremontia californica	

MLRA-22. SIERRA NEVADA RANGE (Continued)

LOWER PONDEROSA PINE FOREST

Native shrubs	Native trees
Prunus virginiana demissa	
Quercus vaccinifolia (higher elevation)	
Rhododendron occidentale	
Ribes nevadense	
Ribes roezlii	
Rubus parviflorus	

At higher elevations include species found in Red Fir Forest, Lodgepole, Jeffrey Pine Forest; at lower elevations include species in Sierra Nevada Foothills (MLRA 18).

RED FIR, LODGEPOLE, JEFFREY PINE FOREST

Native shrubs	Native trees
Amelanchier pallida	Abies concolor
Arctostaphylos nevadensis	Abies magnifica
Arctostaphylos patula	Juniperus communis saxatilis
Artemisia tridentata*	Pinus jeffreyi
Castanopsis sempervirens	Pinus monticola
Ceanothus cordulatus	Pinus murrayana
Ceanothus prostratus	Pinus ponderosa
Ceanothus velutinus	Populus tremuloides
Cercocarpus ledifolius*	Sequoiadendron giganteum (limited range)
Chrysothamnus nauseosus*	
Cornus stolonifera	
Eriogonum umbellatum	
Penstemon laetus	
Penstemon newberryi	
Penstemon speciosus*	
Prunus emarginata	
Purshia tridentata*	
Quercus vaccinifolia	
Ribes nevadensis	
Ribes roezlii	
Rosa woodsii ultramontana*	
Rubus parviflorus	
Salix sp.	
Sambucus microbotrys	

(continued)

MLRA-22. SIERRA NEVADA RANGE (Continued)

RED FIR, LODGEPOLE, JEFFERY PINE FOREST

Native shrubs	Native trees
Symphoricarpos acutus	
Symphoricarpos vaccinioides	

* Mostly limited to the east slope of the Sierra Nevada Mountains.

At higher elevation includes species in Subalpine Forest; at lower elevation includes species in Ponderosa Pine Forest.

Revised 5-2-75

MLRA-26. CARSON BASIN AND MOUNTAINS

This area includes a large part of Central and Eastern Mono County and the Southeastern tip of Lassen County. Elevations range from 3500 feet in valleys to over 10,000 feet in mountains. Precipitation ranges from 3 inches at lower elevations to 16 inches in the mountains.

Native shrubs	Native trees
Amelanchier sp.	Juniperus osteosperma
Artemisia spinescens	Pinus monophylla
Artemisia tridentata	
Atriplex canescens	
Atriplex confertifolia	
Chrysothamnus nauseosus	
Ephedra nevadensis	
Ephedra viridis	
Eriogonum fasciculatum polifolium	
Erotia lanata	
Grayia spinosa	
Kochia vestida	
Lycium andersonii	
Prunus andersonii	
Purshia tridentata	
Sarcobatus vermiculatus	
Tetrodymia glabrata	

Revised 5-2-75

MLRA-29. SOUTHERN NEVADA BASIN AND RANGE

This area includes most of Inyo County west of Bishop, excluding Death Valley, and extends into Mono and San Bernardino counties. Elevations range from 2,000 to 5,500 feet in valleys to over 13,000 feet in mountainous areas. Precipitation ranges from 5 inches at lower elevations to 15 inches in the mountains.

Native shrubs

Artemisia spinescens
Artemisia tridentata
Atriplex canescens
Atriplex conferifolia
Atriplex lentiformis
Chrysothamnus nauseosus
Chrysothamnus stenophyllus
Coleogyne ramosissima
Ephedra viridis
Eriogonum fasciculatum polifolium
Eurotia lanata
Franseria dumosa
Grayia spinosa
Gutierrezia lucida
Hymenoclea salsola
Kochia americana
Larrea tridentata or L. divaricata
Lycium andersonii
Mendosa spinescens
Sarcobatus vermiculatus
Tetrodymia glabrata

Native trees

Juniperus osteosperma
Pinus monophylla

MLRA-30. THE SONORAN BASIN AND RANGE

This area covers a large portion of the desert in southeastern California including the Mojave and Colorado Deserts. Rainfall usually averages less than 5 inches annually, often occurring in thunder showers. Several years may elapse before there is an effective rain and plants germinate. The area is very hot in summer and may have below-freezing temperatures on winter nights. No information has been found of dryland seedings of plantings in this area, mainly because the area is a desert and has been considered impractical to revegetate.

For the purpose of this Study, higher-rainfall areas in the desert are included in MLRA-30. These include the Joshua Tree Woodland, where annual rainfall averages about 6-15 inches, and the Pinyon Juniper Woodland, where annual precipitation ranges from 12 to 20 inches. The Joshua Tree Woodland and the Pinyon Juniper Woodland are strongly influenced by the harsh climatic conditions existing in the desert.

I. The desert, average precipitation about 5 inches or less.

Native shrubs

Acampotopappus sphaerocephalus
Ambrosia dumosa
Artemisia spinescens
Atriplex canescens
Atriplex confertifolia
Atriplex hymenelytra
Atriplex lentiformis
Atriplex parryi
Atriplex polycarpa
Chilopsis linearis (water courses)
Chrysothamnus nauseosus
Encelia farinosa
Eurotia lanata
Fouquieria splendens
Franseria dumosa
Larrea tridentata
Lepidium fremontii
Lycium andersonii
Lycium cooperi
Salazaria mexicana
Simmondsia chinensis

Native trees*

Acacia greggii
Olneya tesota
Prosopis juliflora var. glandulosa
Prosopis pubescens
Washingtonia filifera

* Found in washes or water courses, Washingtonia filifera in moist alkaline places.

MLRA-30. THE SONORAN BASIN AND RANGE (Continued)

II. Joshua tree woodland, average precipitation 6-15 inches, with summer showers.

Native shrubs	Native trees
Acamptopappus sphaerocephalus	Juniperus californica
Artemisia tridentata	
Atriplex canescens	
Atriplex confertifolia	
Atriplex polycarpa	
Atriplex spinifera	
Ceanothus greggii	
Chilopsis linearis (water courses)	
Chrysothamnus nauseosus	
Eriogonum fasciculatum var. polifolium	
Eurotia lanata	
Lycium andersonii	
Lycium cooperi	
Salazaria mexicana	
Simmondsia chinensis	
Tetradymia axillaris	

III. Pinyon juniper woodland, average precipitation 12-20 inches.

Native shrubs	Native trees
Artemisia tridentata	Juniperus californica
Ceanothus greggii	Juniperus osteosperma
Cercocarpus ledifolius	Pinus monophylla
Chrysothamnus nauseosus	
Chrysothamnus viscidiflorus	
Cowania mexicana var. stansburiana	
Quercus turbinella	
Yucca baccata	
Yucca schidigera	
Purshia glandulosa	

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MLRA-31. IMPERIAL VALLEY

Most of these lands are within the broad structural trough which lies north of the delta of the Colorado River in Mexico. The land is nearly level or gently sloping, except where it has been modified by wind or where it was dissected by the New and Alamo Rivers during the flood of 1905 to 1907. Elevations within this area range from about 300 feet above sea level north of Blythe to 240 feet below sea level at the Salton Sea. Annual rainfall rarely exceeds three inches, nearly all as high-intensity summer thunderstorms. These storms produce very high runoff, but contribute little to the soil moisture. Winters are mild, and summers are extremely hot.

Native shrubs

Abronia villosa
Atriplex breweri
Atriplex canescens
Atriplex lentiformis
Atriplex polycarpa
Atriplex spinifera
Cassia sp.
Chilopsis linearis (water courses)
Encelia farinosa
Eriogonum deserticola
Fouquieria splendens
Krameria grayi
Nolina bigelovii
Yucca schidigera

Native trees

Olney tesota
Parosela spinosa
Prosopis juliflora var. glandulosa
Prosopis pubescens

(Only a few species of trees occur, and these are limited to streambeds and borders of springs of low-lying valleys.)

APPENDIX D

Some Common Names and the Varietal and Botanical Names of Shrubs, Trees and Herbaceous Species Mentioned

SOME COMMON NAMES AND THE VARIETAL AND BOTANICAL
NAMES OF SHRUBS, TREES AND HERBACEOUS SPECIES MENTIONED

Common Name	Variety	Botanical Name
Adelia or desert olive		Forestiera neomexicana
Alder, white		Alnus rhombifolia
Alfalfa	Ranger	Medicago sativa
"	Rambler	" "
Arborvitae, giant		Thuja plicata
Aspen, quaking		Populus tremuloides
Azalea, western		Rhododendron occidentale
Balloon pea		Sutherlandia frutescens
Barley	Arivat	Hordeum vulgare
"	Blue mariot	" "
"	Briggs	" "
"	Campana	" "
"	Casbon	" "
"	CM 67	" "
"	Luther	" "
"	Numar	" "
"	Schuyler	" "
Bayberry, northern		Myrica pensylvanica
"		" cordifolia**
" pacific or pacific myrtle		" californica
Beachgrass, American	Cape	Ammophila breviligulata
Bentgrass, colonial	Highland	Agrostis tenuis
" redtop		" alba
Bermuda grass		Cynadon dactylon
Bitterbrush, antelope		Purshia tridentata
" desert		" glandulosa
Blue curls, wooly		Trichostema lanatum
Bluegrass, annual		Poa annua
" big	Sherman	" ampla
" Kentucky		" pratensis
Blackbrush		Coleogyne ramosissima
Bladderpod		Isomeris arborea
Bladder sage		Salazaria mexicana
Bladdersenna, common		Colutia arborescens
Brittlebrush		Encelia farinosa
Brome, California	Cucamonga	Bromus carinatus
" cheatgrass		" tectorum
" field	Cucamonga	" arvensis
" red		" rubens
" seaside		" maritimus
" smooth	Manchar	" inermis
" soft chess	Blando	" mollis
Buckeye, California		Aesculus californica
Buckthorn, California or coffeeberry		Rhamnus californica
" chaparral or coffeeberry		" " tomentella

Common Name	Variety	Botanical Name
Buckthorn, cascara		Rhamnus purshiana
" redberry		" crocea
Buckwheat, California		Eriogonum faciculatum
" "		" " polifolium
" desert		" deserticola
" St. Catherine's lace		" gigantum
" sulfur flower		" umbellatum
Burrobrush, white		Hymenoclea salsola
Bursage, white		Franseria dumosa
California bay, c. laurel, Oregon myrtle		Umbellularia californica
California fan palm		Washington filifera
California wild grape		Vitis californica
Canaryclover, branching		Dorycnium suffreticosum
Canarygrass, reed	Cana	Phalaris arundinacea
" "		" "
Catclaw		Acacia greggi
Ceanothus, blue blossom		Ceanothus thrysiflorus
" prostrate blue blossom		" " repens
" buckbrush or wedgeleaf		" cuneatus
" Carmel creeper		" griseus horizontalis
" cuneatus x prostratus hybrid		" cuneatus x c. prostratus
" chaparral whitethorn		" leucodermis
" coast whitethorn		" incanus
" deerbrush		" integerrimus
" "		" " puberulus
" desert		" greggi
" dwarf		" pumilus
" Fresno mat		" fresnensis
" hoaryleaf		" crassifolius
" jimbush		" sorediatus
" lemon		" lemmonii
" maritime		" maritimus
" mountain whitethorn or snowbush		" cordulatus
" Point Reyes		" gloriosus
" redheart		" spinosus
" Roderick		" roderickii*
" Santa Barbara		" impressus
" squaw carpet		" prostratus
" tobacco brush or snowbrush		" velutinus
" wartleaf		" papillosus
" wavyleaf		" foliosus
" wollyleaf		" tomentosus
Cereal rye, common	Black	Secale cereale
" "	Merced	" "
Cedar, incense		Libocedrus decurrens
" Port-Orford		Chamaecyparis lawsonia

Common Name	Variety	Botanical Name
Chamise		Adenostema fasciculatum
" redshanks, ribbonwood		" sparsifolium
Chaparral pea		Pickeringia montana
Cherry, bitter		Prunus emarginata
" Catalina		" lyonii
" hollyleaf		" ilicifolia
" western choke		" virginiana demissa
Chinquapin, golden		Castanopsis chrysophylla
" Sierra, bush		" sempervirens
Cliffrose		Cowania mexicana stansburiana
Clover, bur		Medicago hispida
" crimson		Trifolium incarnatum
" rose	Wilton, Hykon	" hirtum
" Spanish		Lotus americanus
" strawberry	Salina	Trifolium fragiferum
" subterranean	Mt. Barker	" subterraneum
" white	Dutch	" repens
Coffeeberry or California buckthorn		Rhamnus californica
" Sierra		" rubra
Cotoneaster		Cotoneaster horizontalis
Cottonwood, black		Populus trichocarpa
" Fremont		" fremontii
Coyote brush or Coyote bush		Baccharis pilularis consanguinea
Coyote brush, prostrate or dwarf	Twin Peaks and an unnamed variety	Baccharis pilularis
Creosote bush		Larrea tridentata (divaricata)
Crownvetch	Chemung	Coronilla varia
Currant, Sierra		Ribes nevadensis
Cypress, dwarf		Cupressus pygmaea
" Saharan		" depreziana
" Sargent		" sargentii
Dallis grass		Paspalum dilatatum
Dogwood, Pacific		Cornus nuttalli
" redosier or American		" stolonifera
Desert willow		Chilopsis linearis
Elderberry, blueberry		Sambucus caerulea
" Mexican		" mexicana
" bunchberry		" microbotrys
Encelia, California		Encelia californica
Ephedra, green or Morman tea		Ephedra viridis
" Nevada		" nevadensis
Eriophyllum, goldenyarrow		Eriophyllum confertiflorum
Escallonia, white		Escallonia macrantha
Fescue, foxtail		Festuca megalura
" hard	Durar	" ovina var. duriuscula
" tall	Alta	" arundinacea
" "	Goar	" "

Common Name	Variety	Botanical Name
Fir, California red		Abies magnifica
" grand		" grandis
" white		" concolor
" bigcone Douglas or bigcone spruce		Psuedotsuga macrocarpa
" Douglas		" menziesii
Flannel bush, California or fremontia		Fremontodendron californicum
" " dwarf or fremontia		" " decumbens*
" " Mexican or remontia		Fremontodendron mexicana
Goatnut, jojoba		Simmondsia chinensis
Goldenhead		Acamptopappus sphaerochephalus
Gooseberry, rock		Ribes quercetorum
" Sierra		" roezlii
Grape, California wild		Vitis californica
Greasewood		Sarcobatus vermiculatus
Harding grass	Hardinggrass	Phalaris tuberosa stenoptera
Hazel, California		Corylus cornuta californica
Hemlock, mountain		Tsuga mertensiana
" western		" heterophylla
Horsebrush, littleleaf		Tetradymia glabrata
" longspine		" axillaris
Hopsage, spiny		Grayia spinosa
Iodine bush or pickleweed		Allenrolfia occidentalis
Johnson grass		Sorghum halepense
June berry		Amelanchier pallida
Juniper, California		Juniperus californica
" common or dwarf		" communis saxatilis
" shore	Emerald Sea	" conferta
" Utah		" osteosperma
" western		" occidentalis
Koleagrass	Perla	Phalaris tuberosa hirtiglumis
Krameria, grayia		Krameria grayi
Lilac, common		Syringa vulgaris
Locust, bristly	Arnot	Robinia fertilis
Lupine, sickle-keeled		Lupinus albicaulis
" Texas bluebonnet		" texensis
" annual		" bicolor
" sky		" nanus
"		" sp.
Madrone, Pacific		Arbutus menziesii
Manzanita, bearberry or kennikinnick		Arctostaphylos uva-ursi
" bigberry		" glauca puberula
" common		" manzanita
" Eastwood		" glandulosa
" glossyleaf		" nummularia
" greenleaf		" patula
" Indian		" mewukka
" Mariposa		" mariposa

Common Name	Variety	Botanical Name
Manzanita, Parry		Arctostaphylos parryana
" pink bracted		" pringlei drupacea
" pine		" parryana pinetorum
" pinemat		" nevadensis
" sandmat		" pumila
" whiteleaf		" viscida
" wooly		" tomentosa
Maple, bigleaf		Acer macrophyllum
" vine		" circinatum
Medic, tree		Medicago arborea
Melaleuca, drooping		Melaleuca armillaris
Mendora, spiny		Mendora spinescens
Mesquite, honey		Prosopis juliflora glandulosa
" tornillo or screw bean		" pubescens
Milkvetch, cicer	Cicar	Astragalus cicer
" "	Lutana	" "
Monkey flower, northern bush		Mimulus aurantiacus
" " southern bush		" longiflorus
Mountain mahogany, birchleaf		Cercocarpus betuloides
" " curlleaf or desert		" ledifolius
" " ironwood		" betuloides macrourus
Mountain misery or bearmat		Chamaebatia foliolosa
Nama, wooly		Nama lobbii
Nolina, Bigelow		Nolina bigelovii
Oak, tan		Lithocarpus densiflora
"		Quercus
" blue		" douglassii
" California live		" agrifolia
" California black		" kelloggii
" California white or valley white		" lobata
" California scrub		" californica
" canyon		" chrysolepis
" Engelmann		" engelmannii
" huckleberry		" vaccinifolia
" interior		" wislizenii
" "		" " frutescens
" Oregon white		" garryana
" Sadler		" sadleriana
" scrub		" dumosa
" shrub		" turbinella
Oats	Curt	Avena sativa
Ocean spray or creambush rockspirea		Holodiscus discolor
Ocotillo		Fouquieria splendens
Oleander		Nerium oleander
Olive, autumn	Cardinal	Elaeagnus umbellata
" Russian		" angustifolia
Orchardgrass	Akaroa	Dactylis glomerata

Common Name	Variety	Botanical Name
Orchardgrass	Berber	Dactylis glomerata
"	Latar	" "
"	Palestine	" "
"	Potomac	" "
"	Pomar	" "
Oregon grape		Mahonia acquifolium
Pea shrub, Siberian		Caragana arborescens
Pea, flat	Lathco	Lathyrus sylvestris
Peach, desert or Nevada wild almond		Prunus andersonii
Pear	Bradford	Pyrus calleryana
Pennisetum, feathertop		Pennisetum villosum
" fountain grass		" ruppelii
Penstemon, mountain blue		Penstemon laetus
" mountain pride		" newberryi
" showy		" speciosus
" Rocky Mountain	Bandera	" strictus
Pickleweed		Salicornia subterminalis
Pine, beach		Pinus contorta
" Bishop		" muricata
" Coulter or bigcone		" coulteri
" digger		" sabiniana
" Jeffrey		" jeffreyi
" knobcone		" attenuata
" lodgepole		" murrayana
" Monterey		" radiata
" Parry or fourleaf		" quadrifolia
" pinyon		" edulis
" ponderosa or yellow		" ponderosa
" singleleaf or one-leaved		" monophylla
" sugar		" lambertiana
" Torry		" torreyiana
" western white		" monticola
Poppy, California		Eschscholzia californica
" tree		Dendromecon rigida
" Matilija		Romneya coulteri
Quakinggrass, big		Briza maxima
Rabbitbrush, Douglas		Chrysothamnus viscidiflorus
" rubber		" nauseosus
" small		" stenophyllus
Ragweed		Ambrosia dumosa
Redberry buckthorn		Rhamnus crocea
Redbud, California or western		Cercis occidentalis
Rhododendron, California		Rhododendron macrophyllum
Ricegrass, Indian		Oryzopsis hymenoides
" smilo		" miliacea
Rockrose		Cistus villosus
" Descanso hybrid		" albidus x crispus
" sageleaf		" salvifolius

Common Name	Variety	Botanical Name
Rose, Nootka		Rosa nutkana
" Wichura or memorial		" wichuraiana
" Woods		" woodsii
Rosemary		Rosmarinus officinalis
Ryegrass, annual		Lolium multiflorum
" perennial	Ariki	" perenne
" wimmera	Wimmera 62	" rigidum
Sage, black		Salvia mellifera
" creeping		" sonomensis
" purple		" leucophylla
" white		" apiana
Sagebrush, big or Basin		Artemisia tridentata
" black or hoary		" cana
" bud		" spinescens
" low		" arbuscula
" California		" californica
" Caucasian		" caucasica
Salal		Gaultheria shallon
Saltbush, Australian		Atriplex semibaccata
" Brewer		" lentiformis breweri
" desert, allscale or cattle		" polycarpa
" desert holly		" hymenolytra
" fourwing		" canescens
" Gardner		" gardneri
" Mediterranean		" halimus
" Nuttall		" nuttallii
" Parry		" parryi
" quailbush		" lentiformis
" shadscale		" confertifolia
" spinescale		" spinifera
Senna		Cassia sp.
Sequoia, giant		Sequoiadendron giganteum
Sheepbush, ruby		Enchylaena tomentosa
Silktassel		Garrya flavescens
" veach		" veatchii
Smilo		Oryzopsis miliacea
Smoketree		Parosela spinosa
Snakeweed		Gutierrezia lucida
Snowberry, desert		Symphoricarpos longiflorus
" sharpleaf		" acutus
" whortleleaf		" vaccinoides
Spruce, Sitka		Picea sitchensis
Squirreltail		Sitanion hystrix
Sweet clover, annual		Melitotus indica
" " yellow blossom		" officinalis
Sumac, laurel		Rhus laurina
" lemonade		" integrifolia
" squawbush or skunkbush		" trilobata

Common Name	Variety	Botanical Name
Sumac, sugar or sugarbush		Rhus ovata
Summercypress, green molly		Kochia americana
Sycamore, California		Platanus racemosa
Tesota or Arizona ironwood		Olneya tesota
Thimbleberry		Rubus parviflorus
Thistle, star		Centaurea solstitialis
Trefoil, birdsfoot	Cascade	Lotus corniculatus
" "	Dwarf English	" " arvensis
" narrowleaf	Los Banos	" tenuis
" Spanish		" americanus
Toyon		Heteromeles arbutifolia
Turkey muellin or dove weed		Eremocarpus setigerus
Verbena, sand		Abronia villosa
Vetch, woolypod	Lana	Vicia dasycarpa
Walnut, California		Juglans californica
Wheat	Bluebird 2	Triticum aestivum
"	D 6923	" "
"	Galglass	" "
"	Nugaines	" "
Wheatgrass, Fairway crested	Fairway	Agropyron cristatum
" standard crested	Nordan	" desertorum
" intermediate	Amur	" intermedium
" "	Greenar	" "
" "	Mandan	" "
" "	Oahe	" "
" "	Tegmar	" "
" pubescent	Luna	" trichophorum
" "	Topar	" "
" "	Trigo	" "
" slender	Primar	" trachycaulum
" streambank	Primar	" riparium
" tall	Alkar	" elongatum
" thickspike	Critana	" dasystachyum
" western	Barton	" smithii
" "	727	" "
Wildrye, beardless		Elymus triticoides
" mammoth	Volga	" giganteus
Willow		Salix sp.
" dwarf arctic		" purpurea nana
" Goodding		" gooddingii
" Pacific		" lasiandra
" slender purple		" purpurea gracilis
" smooth		" laevigata
Winter fat		Eurotia lanata
Wolfberry, Anderson or Anderson desert thorn		Lycium andersonii
" Cooper or Cooper desert thorn		" cooperi

Common Name	Variety	Botanical Name
Yerba santa, California		Eriodictyon californicum
" " hairy		" trichocalyx
Yucca, Joshua		Yucca brevifolia
" Mojave		" schidigera
" whipple, Our Lord's Candle, Quixote		" whipplei
" Spanish bayonet		" baccata
		Chrysanthemoides monilifera**

* Local endemic, rare
** Common name not known